Sky and TELESCOPE

Armagh Observatory

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Vol. XV, No. 3

JANUARY, 1956

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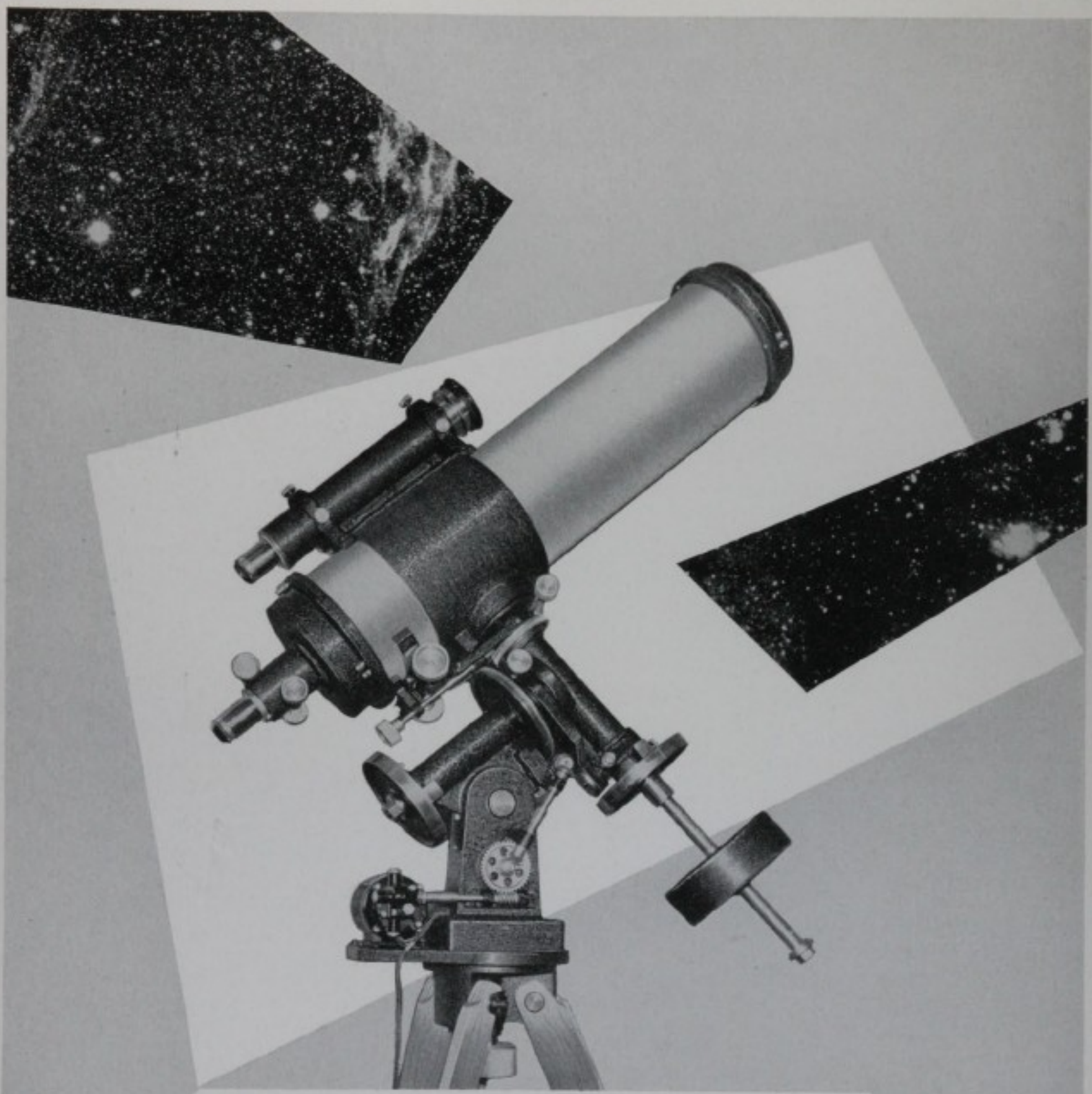

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COVER: Armagh Observatory, at Armagh, North Ireland, as seen from the south. The domes in the foreground house a 10-inch refractor (left) and a new 12-inch Schmidt telescope (right). The latter has been used to study variable stars and comets. The square structure just beyond the wooden gate houses E. J. Opik's vibrating camera for meteors. In the left background is the director's residence and observatory offices, surmounted by a dome containing a 3-inch refractor that was part of the original equipment of the observatory. Photograph by H. Allison and Son, Armagh. (See page 120.)

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FEATURE PICTURE: A removable finding map of the moon, identifying some 350 of its craters and other features conspicuous in small telescopes. As with all lunar charts, south is above and west to the left; the view matches that in an astronomical or inverting telescope. The basic map is reduced to about half size from Karel Andel's Mappa Selenographica, first published at Prague, Czechoslovakia, by Joseph Klepesta, in 1926. (See page 108.) Center

SKY AND TELESCOPE is published monthly by Sky Publishing Corporation, Harvard College Observatory, Cambridge 38, Mass. Entered as second class matter, April 28, 1939, at the Post Office, Boston, Mass., under Act of March 3, 1879; accepted for mailing at the special rate of postage provided in Paragraph 4, Section 538, Postal Laws and Regulations.

Subscriptions: $4.00 per year in the United States and possessions; $7.00 for two years; $10.00 for three years. Add $1.00 per year for Canada, Mexico, and all countries of the Pan American Postal Union, making the total subscription $5.00 for one year; $9.00 for two years; $13.00 for three years. Add $1.50 per year for all other foreign countries, making the total subscription $5.50 for one year; $10.00 for two years; $14.50 for three years. Canadian and foreign remittances should be made in United States currency. Single copies 40 cents, foreign 50 cents.

All notices of change of address must be sent one month in advance and accompanied by old and new addresses. When sending your renewal order, or writing in regard to your subscription, your current mailing address must be given. Please return our bill form with your renewal payment. Circulation manager, Nancy R. Bolton.

Editorial and advertising offices: Harvard College Observatory, Cambridge 38, Mass. Advertising manager, Henry M. Corrado. Unsolicited articles and pictures are welcome, bearing adequate return postage, but we cannot guarantee prompt editorial attention, nor are we responsible for the return of unsolicited material. Photographs should be glossy prints, minimum size 4 by 5 inches.

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A New American Observatory

SINCE the Palomar and McDonald observatory projects some 25 years ago, no new major astronomical observing center in the United States has been planned. This was brought out by Dr. A. E. Whitford, of Washburn Observatory, University of Wisconsin, in an after-dinner talk to the American Astronomical Society at its Troy, N. Y., meeting on November 10th.

His subject was the plan for a new American observatory, to be erected at a yet undetermined site in the arid regions of the southwestern United States, its principal instrument probably to be an 80-inch Cassegrainian reflector. Preliminary site surveys are well under way, with Dr. A. B. Meinel, Yerkes Observatory, acting as executive secretary of the project. Since July the program has been greatly expanded with the aid of a $279,000 National Science Foundation grant to the University of Michigan.

The first proposal to the NSF, made by the University of Arizona, Indiana University, and Ohio State University, was a result of the trend of astrophysical research toward precision photometry, and the increasing use of a much wider range of wave lengths than can be brought into sharp focus by refracting telescopes. Dr. Whitford pointed out that many of the older observatories in the more populous sections of the country are at a disadvantage in attacking modern problems, because they have poor observing conditions and instrumental limitations.

To map the needs for a new observatory, in 1953 the NSF sponsored a conference on photoelectric astronomy at Lowell Observatory. At this meeting it was urged that a co-operative center for all types of observation would provide a great stimulus to American astronomy. This viewpoint was adopted by the NSF in 1954, as part of its effort to strengthen the long-term growth of science in America, and an advisory panel was appointed to study the proposal. Committee members are: chairman, Dr. Robert R. McMath, McMath-Hulbert Observatory; Dr. Ira S. Bowen, Mount Wilson and Palomar Observatories; Dr. Bengt Stroemgren, Yerkes Observatory; Dr. Otto Struve, Leuschner Observatory; and Dr. Whitford. This committee held its first meeting in November, 1954.

Although the research to be done at the new observatory would provide ample justification for building it, of equal importance would be its educational functions. Dr. Whitford said:

"Such a national observing center would lessen the reluctance of young astronomers to accept posts in institutions

(Continued on page 111)

The Origin of the Moon's Surface Features — I

HAROLD C. UREY, *Department of Chemistry*
and Enrico Fermi Institute for Nuclear Studies, University of Chicago

SINCE THE publication of R. B. Baldwin's book, *The Face of the Moon*, in 1949, there has been little reason to argue the old question of collisions versus plutonic action as the cause of the large craters. Most of the collision arguments were advanced by G. K. Gilbert in 1893 and have been ignored or discarded for much too superficial reasons by subsequent students. The plutonic theory of crater origin was advanced before the modern scientific world knew that meteorites fell on the earth, and it has required nearly a century of discussion for astronomers substantially to agree that the moon's surface was fashioned mostly by collisions.

Gilbert showed that most lunar structures are not similar to terrestrial ones, that the pattern of overlap of the craters is that expected for chance collisions, and he discussed many other points. Baldwin marshalled the evidence most effectively and conclusively. We assume that most of the lunar features are due to collisions of objects with its surface, though some small formations were caused by plutonic processes of a volcanic type, and explanations must be given for what appear to be lava flows.

[The map of the moon in the center of this issue should be referred to in conjunction with Dr. Urey's article. It is removable for study and telescope use.]

The keys to the origin of the surface features of the moon, and hence to the origin of the moon as a whole, are its irregular shape and the great collision in Mare Imbrium. There are many subsidiary lines of evidence, but we begin our discussion with these two important points.

The Moon Was Accumulated at Low Temperatures

Definite evidence for the moon's irregular shape comes from its dynamical motions. Textbooks on celestial mechanics give the formula for computing from observation the difference in the moon's moments of inertia about its three axes. The numerical values indicate that the moon's radius toward and away from our earth is greater than the radius along the poles, by about one kilometer; whereas the equilibrium value resulting from the forces acting on the moon should be only 60 meters. This irregular shape results in a difference of stresses at the moon's center of about 20 atmospheres, and this requires the strength of the moon's substance at its center to be about that of brick. Therefore, the center of the moon cannot be a liquid at the present time.

The next important point is that an object as large as the moon can cool only very slowly, even in a time as long as the moon has existed, which we believe to be 4½ billion years. This now seems a well-established age of meteorites, from three methods of dating by radioactive elements. The cooling of a sphere is a readily solved problem in terms of its thermal conductivity, which is also a known quantity for igneous rocks. Such a calculation, made by the writer some years ago, shows that the center of the moon will lose very little of its heat in 4.5×10^9 years. (The original calculation has been repeated using more recent data, and the statement refers to these revised calculations.) If the moon were ever molten, then the center must be close to the melting point now, and hence it would not have the required strength to support the irregular shape.

The presence of the radioactive elements, potassium, uranium, and thorium, would increase the temperatures throughout the moon. The extent to which the temperatures are raised by this source of heat depends upon the amounts and distribution of these elements in the moon. We have no direct evidence in regard to these data for the moon and, in fact, have great difficulty in estimating them for the earth. However, if the rate of heat loss from the interior of the earth is now entirely due to heat generated from radioactive substances, we can estimate the amounts of these elements in the earth as a whole. Then, from analytical data on the rocks and our knowledge of the thickness of the crust from seismic data, we can conclude that perhaps one third to one half of this radioactive material is now in the earth's crust and the remainder is probably distributed throughout the earth's mantle. Similar amounts of radioactivity, distributed in the same way, would require the interior of the moon to be melted or near its melting point out to about 0.8 of its radius, if its initial temperature were at the melting point.

Such a conclusion is inconsistent with our satellite's irregular shape. Hence, the moon must have been formed at low temperatures and never heated by radioactive sources to its melting point. It is not now as plastic as the earth, and the partial melting processes that have produced the crust of the earth cannot have occurred within the moon, and thus the radioactive elements have not been concentrated at the moon's surface by these melting processes. In 1893 Gilbert said, "During the whole period of growth the body of the moon was cold." This statement was made before the discovery of radioactivity. Radioactive heating has caused much trouble in reaching Gilbert's conclusion again, and the problem is a critical one. In fact, this very character makes the problem so informative about a number of subjects.*

The Imbrian Collision

The great collision in Mare Imbrium was discovered by Gilbert in 1893. In the composite picture (Fig. 1), the region of this collision is shown. It is not possible to see much detail in a picture of the full moon, yet unless both halves of the moon are shown, the relationships between the two are not observed. Fig. 2 exhibits the Imbrian region as it would appear to an observer above Mare Imbrium looking toward Sinus Iridum. This picture was obtained by projecting photographs of the moon upon a sphere, and then photographing the sphere from the proper angle. We see that, with foreshortening thus eliminated, the crater Plato is circular in outline in this picture and not elliptical as ordinarily observed. Superimposed on Fig. 2 is a drawing outlining the relative positions of Sinus Iridum, a circular area before it, and the entire Mare Imbrium. Radiating from the circular area are many grooves and ridges, particularly near the center of the moon's disk. Gilbert noted all these features,

*Those who wish to consider this subject in detail should read the author's paper on "The Cosmic Abundances of Potassium, Uranium, and Thorium and the Heat Balances of the Earth, the Moon, and Mars," *Proceedings*, National Academy of Sciences, *41*, 127-144, March, 1955.

Fig. 1. A composite picture of the moon made by matching photographs taken at first and last quarter, with the 36-inch Lick refractor on Mt. Hamilton, Calif., by Moore and Chappell. The western (left) portion is from an exposure on May 6, 1938, the eastern portion from one on October 26, 1937. While the pictures have been matched at the center, they fail to correspond exactly at the poles, because of the difference in the moon's libration at these two dates. Compare the Mare Imbrium region (lower right) with its appearance in Fig. 2. Lick Observatory photograph.

except what appears to the writer to be the completely obvious relationship of Sinus Iridum to the rest of the pattern. It is certain that this pattern originated in one event, and that this event was the collision of a large object with the moon. The pattern of ridges and grooves and of the deep area before Sinus Iridum is unsymmetrical. Hence, this object arrived from the northeast at a substantial angle from the vertical, bored out a deep hole in the moon, and spread some of its substance and some of the moon's substance in a wide pattern for great distances over the moon's surface.

The complexities of this pattern and the lessons to be learned from them are very great. Let us first consider the extent of the ridges and grooves. A few extend through the Jura Mountains to the northeast of Sinus Iridum. The principal pattern spreads out in a semicircular fan, from the neighborhood of Plato to the eastern edge of the Carpathians. Mountainous masses near Theophilus and a groove through Capella may belong to this system. Other grooves extend out

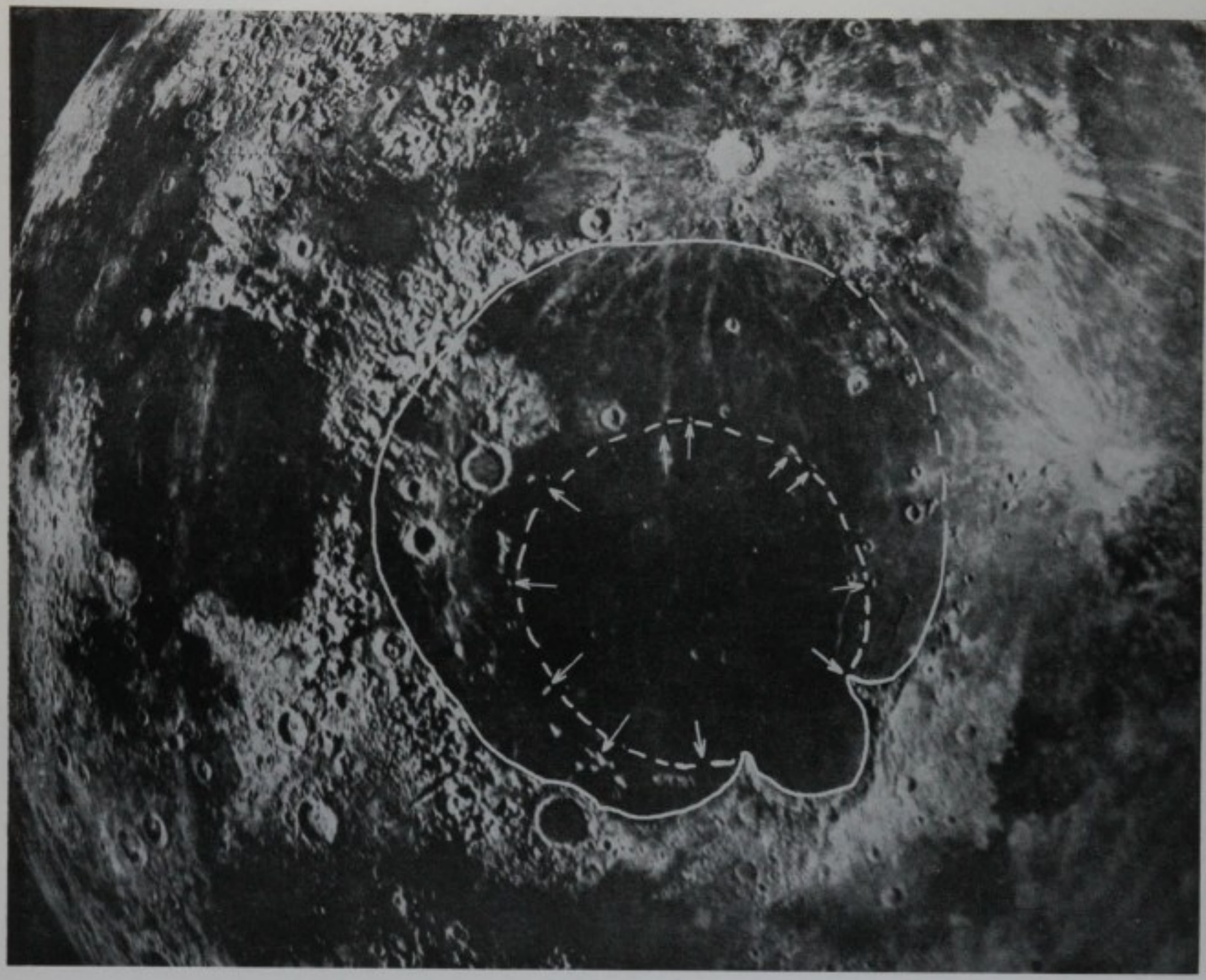

Fig. 2. This photographic composite of three pictures of the moon projected on a sphere was obtained by the author to show the structures produced by the proposed Imbrian collision. It is not intended for ordinary chart purposes. South is at the top. Mare Imbrium, outlined by the solid curve, is seen as if the viewer were directly above it. Copernicus is the large bright crater south of Mare Imbrium; Sinus Iridum is the semicircular bay on the lower right (within the solid curve); left of this is the great dark-floored ring plain, Plato. Neither large craters nor mountains occur inside the dashed circle that marks the collision area. The arrows indicate mountainous masses just outside this circle; three arrows point to masses not seen in the picture but easily detected on good originals. University of Chicago photograph.

through the walls of Ptolemaeus and Alphonsus and out to about Arzachel. In Oceanus Procellarum there are many short ridges with a general orientation toward the collision area. Oftentimes one is not sure about the relationship of a particular ridge to the system, but the over-all pattern is entirely convincing.

The velocity of an object in a surface-grazing orbit about the moon is 1.7 kilometers per second, and since these objects fell some 1,000 or 1,500 kilometers from the point of the collision, they must have been moving with about this speed. I can find no evidence for objects with much higher velocities. The distribution of these grooves and ridges indicates that the colliding body or planetesimal arrived with moderate speed. If the velocity had been 30 kilometers per second, for example, the object would have behaved like an explosive, making a symmetrical crater. But with a low arrival speed, say 2.4 kilometers per second, the escape velocity of the moon, the pattern can be understood. This is less than the speed of sound in its material, and on impact some of the top and back parts should have flown off nearly horizontally at perhaps 1.7 kilometers per second. Other reasons for accepting the low impact velocity of 2.4 kilometers per second will be given later. The use of this value implicitly assumes that the object was a satellite in the earth-moon system.

How large was the object? This planetesimal either produced Sinus Iridum as it plowed into the moon, or fell on a previous walled plain in exactly this location, destroying one half of the structure cleanly and exactly, so that the remnant faces precisely the circular area in Mare Imbrium. I think it is most probable that it produced Sinus Iridum and that the distance of 230 kilometers between the two promontories of Laplace and Heraclides is approximately, but somewhat greater than, the diameter of the planetesimal, which was estimated by Gilbert on less direct grounds as 160 kilometers. Other estimates have been made, but I believe these two are sufficient.

We take a diameter of 200 kilometers as most likely. With a density of 3.5, the mass of the body would have been 1.47×10^{22} grams. Using 2.38 kilometers per second as its velocity, the kinetic energy at collision was 4.15×10^{32} ergs. This is equivalent to 4.6×10^{11} atomic bombs. (An atomic bomb is taken as the energy of conversion of one gram of mass to energy.) This number would be sufficient to place one such bomb on each 1,100

square meters of the earth's surface, just about one for every fair-sized city lot.

A collision of this magnitude is completely beyond any experience that we have had on earth, and it would be very difficult to extrapolate to it from our puny terrestrial experiments. We accordingly may take this collision as an observed fact and conclude that this pattern on the moon shows us what such an energetic collision would produce. Evidently, the object plowed into the solid surface, flattened out in the collision area, produced an elevated bulge in the moon's surface all around this area but more in the direction toward which the object moved, namely toward the center of the moon's apparent disk. This bulged area was badly broken up, perhaps even to fine sand, and after the collision part of the loose material subsided again, producing the shelf area between the inner and outer rings of our Fig. 2.

Part of the surface of the moon was lifted and dropped as big chunks, forming the Straight Range, Piton, Pico, Spitzbergen, and so on, within Mare Imbrium; and the Alps, Apennines, Caucasus, and Carpathian mountains. The Alps and Caucasus look particularly like this sort of material. On the other hand, the Carpathians and the Apennines may consist of part of the planetesimal. Great masses of the planetesimal formed the Haemus Mountains and produced the grooves. But it requires high-density material to cut these long grooves and this material must be nickel-iron alloy; it is most probable that it was part of the planetesimal because of the great distance of the grooves from the point of origin. Such nickel-iron objects remind us of iron meteorites. Presumably, this planetesimal was made by the same processes as those which produced the parent of the meteorites.

Other circular maria are Crisium, Nectaris, Humorum, and Serenitatis. The Altai Mountains are a scarp to the south and east of Mare Nectaris; and it is possible to trace vestiges of this scarp as a ring about 100 kilometers from the edge of the mare for three quarters of the way around it. It appears to be similar to the Alpine, Apennine, and Carpathian scarps of Mare Imbrium, and is so interpreted by Baldwin. The Rheita and Borda valleys and other grooves look as though they might have been cut by flying missiles, but it is difficult to feel certain about this. Baldwin believes that there are radiating ridges around other maria, but they are certainly less evident.

Always we should remember that there is another hemisphere of the moon which we cannot see; if we could, perhaps many things would be clearer. However, it does seem reasonable to assume that the large planetesimal of Mare Imbrium was not the only one to fall on the moon, and I believe that each of these circular maria is the scar produced by the fall of such a large object. These objects may have fallen more nearly from the vertical and hence not have given such a wide unsymmetrical fan of ridges and grooves. Also, the shelf area of Mare Nectaris out to the Altai Mountains is not noticeably covered with the smooth gray material of the maria.

When Did these Collisions Occur?

Some of the ordinary large craters, which we are assuming were formed by collisions, antedate the Imbrian collision and others postdate this event. Thus Ptolemaeus has walls which are scarred by the missiles from the Imbrian collision. Over one side of its crater, Julius Caesar has a mountainous mass which is part of the debris. On the other hand, Aristillus and Autolycus lying within Mare Imbrium are later craters. In some cases, we may be uncertain. Thus it could be argued that Plato and Archimedes are either older or younger than Mare Imbrium. Similar relationships are evident for the other circular maria. Surely Theophilus postdates Mare Nectaris, as do other craters in the neighborhood. Evidently, all these collisions were part of a single series of events: Some craters were formed, then a mare, then still more craters and another mare, and so on, and these craters and maria covered the entire surface of the moon densely enough to have completely broken up its surface rocks. If the moon was near the earth while this happened, the earth should have been bombarded more intensely than the moon because of the greater energy of the objects arriving at the earth. Furthermore, the earth with its greater gravitational field would have a larger effective collision radius than the moon and hence more objects would fall per unit time. Such a bombardment would have destroyed all the terrestrial sedimentary record. The oldest sedimentary rocks which have been reliably dated are about three billion years old. Perhaps this bombardment occurred between $4\frac{1}{2}$ and three billion years ago. This is long enough in the past so that one wonders whether what we see on the moon is not a record of the last phases of the formation of the earth and moon.

(To be continued)

A NEW AMERICAN OBSERVATORY

(Continued from page 107)

where opportunities have thus far been limited to teaching. By opening a path to continued professional development for a young astronomer, the new observatory could contribute very materially to raising the general level of staff competence in the colleges and smaller universities. This could result in an increase in the number of gifted students in these colleges who would be influenced toward an astronomical career."

In selecting the site, the primary considerations are an atmosphere of the highest possible transparency, and excellent seeing as well. These requirements call for the general region of the Southwest, preferably in a climatic zone with a weather pattern "out of phase" with that of the Pacific Coast, where so many of our large telescopes are situated. Already the reconnaissance of possible sites is nearly complete, and systematic tests of sky conditions are about to begin. These tests are to include measurements from piers 60 feet high, in order to determine seeing conditions for solar tower telescopes.

As soon as the search is narrowed down to a few promising sites, it is proposed to use a 36-inch reflector on a temporary mounting for actual photoelectric observations, which would allow a definite decision as to final location. Thereafter, work could be begun on the first major instrument. According to present proposals, this 80-inch Cassegrainian would be completed by the end of the first five years of the project.

It is expected that operation of the future observatory will be by an association of universities, probably principally by institutions in climatically less favored parts of the country, whose astronomers would be the main users of the new instruments. But the facilities would be made available on the basis of merit rather than on the institutional connection of an applicant.

Should the chosen site prove exceptionally suitable, the observatory could grow in the future to include perhaps an even larger main telescope, as well as instruments for studying the sun.

EUGENE DELPORTE

Eugene Delporte, director of the Royal Observatory of Belgium at Uccle from 1936 until 1947, died in October at the age of 73. Known particularly for his discovery of the remarkable minor planets Amor in 1932 and Adonis in 1936, Dr. Delporte had long been in charge of the extensive observations of asteroids at Uccle. During his association with the Royal Observatory since 1903, he was also active in the compilation of star catalogues and in time and longitude determinations.

Dr. Delporte was a leader in promoting co-operation in astronomy, having served on the Belgian national committee for astronomy from its founding in 1919, and as its president from 1947 to 1955. He was a member of the International Astronomical Union's commissions for asteroids, planetary observations, and longitudes; and in 1930 he edited the two volumes establishing the now internationally accepted boundaries of the constellations. He was a vice-president of the Belgian Astronomical Society from 1927 until his death.

AMERICAN ASTRONOMERS REPORT

Here are highlights of some papers presented at the 93rd meeting of the American Astronomical Society at Troy, N. Y., in November. Complete abstracts will appear in the Astronomical Journal.

Interstellar Grain Formation

In general, the light of more distant stars appears dimmer than that of stars near to us, type for type, and this dimming is attributed to the action of particles of interstellar matter that are about 1/10,000 millimeter in size, according to classical electromagnetic theory. Although grains of smaller dimensions are expected to be more numerous, they have been thought to make a negligible contribution to interstellar extinction.

Now J. R. Platt and B. Donn, University of Chicago, suggest that quantum processes enable certain much smaller molecules to absorb starlight appreciably in the visible region of the spectrum. They deduce that a mixture of grains with dimensions of only 10 to 50 angstroms (10^{-6} to 5×10^{-6} millimeter) can give continuous extinction in the visible region, decreasing toward the red because the larger particles are less frequent.

Among other favorable characteristics, these small particles would tend to be elongated because of statistical fluctuations in a random growth process involving small numbers. If aligned by such a mechanism as an interstellar magnetic field, they may be expected to produce several per cent of polarization in the starlight passing through them. The polarization of starlight in many regions of the Milky Way galaxy has already been observed, but is only partly explained.

The Chicago scientists believe that the formation of such small interstellar grains may result from their chemical rather than purely physical behavior. They said, "Interstellar matter, consisting primarily of atomic species, must be a highly reactive medium."

At the low densities of the space between the stars, all building-up processes would be caused by two-body collisions. The large hydrogen abundance makes reactions with this element most significant, for instance, between hydrogen and such free radicals as CH, which seems likely to be produced with an appreciable concentration. Collisions among already formed radicals also should be significant, as well as the direct addition of atoms to growing particles. Oxygen, nitrogen, and especially carbon will be important in the building-up process, since only a limited number of hydrogen atoms can be chemically captured by each heavier atom.

This hypothesis differs from previous treatments of the subject in that chemical bonding plays the dominant role throughout the entire development of each grain. The rate of growth will probably be slow. It is expected that charged, quasi-organic radicals frequently having unsaturated bonds will result from this mechanism. This is just the structure required for the optical properties of interstellar particles.

The Artificial Satellite

"First matter and energy, and now space will have become the slaves of man."

With these prophetic words, Dr. Fred L. Whipple, director of the Smithsonian Astrophysical Observatory, concluded his report on the earth satellite program of the United States government. The Harvard astronomer believes the possibility of making continuous astronomical observations above the earth's atmosphere is of "huge scientific importance."

The sponsor of the American satellite effort is the National Academy of Sciences, working through the U. S. National Committee for the International Geophysical Year, whose chairman is Dr. Joseph Kaplan, University of California. With financial support from the National Science Foundation, the Department of Defense is conducting Project Vanguard, the satellite program, under Navy management. Dr. John P. Hagen, Naval Research Laboratory, is the project leader.

At Troy, Dr. Kaplan announced the membership of the technical panel of scientists responsible for planning the scientific aspects of the satellite. The nine-man panel is headed by R. W. Porter, of General Electric Co., and includes two astronomers, Dr. Whipple and Dr. Lyman Spitzer, Jr., Princeton University Observatory.

Work on the engineering aspects of the project is currently under way, both at the Department of Defense and at the National Academy. Since many of the relevant facts about the satellite and its proposed orbit are undetermined or liable to change, there is still uncertainty about a matter of great interest to astronomers —planning of radio and optical tracking of the satellite. Therefore, Dr. Whipple discussed the visibility of the artificial satellite on the basis of reasonable assumptions. He suggested that the orbit be oriented so the satellite would pass over some fixed astronomical observatories. In this case, transit circle observations might be feasible and permit the accurate measurement of the satellite's position. Precise timing of any positional observations will be of great importance, as the object will travel some 18,000 miles an hour, or 80 meters in 1/100 second.

The following highlights have been taken from Dr. Whipple's talk:

"The satellite will move in an orbit above the denser lower part of the atmosphere in order that the atmospheric drag will not bring it down too quickly. Perigee distances greater than 200 miles have been mentioned. The period of the object will be about an hour and a half, depending upon the precise values of perigee and apogee after launching. The greater these distances, the longer the satellite will remain in its orbit because of the reduced atmospheric resistance. We may hope that the satellite will remain in its orbit for months or years rather than days, although a complete knowledge of the satellite and its initial orbit would not, at the present moment, give us an indication of its lifetime to an accuracy better than about a factor of 10.

"The apparent brightness will depend upon the satellite's dimensions, albedo, and distance from the observer. Under ideal circumstances of zenithal observation in late evening or early morning twilight, we may postulate, on the basis of published statements, that it may be as bright as visual magnitude 5 to 7, near the limit of naked-eye visibility, but easily observable under ideal atmospheric circumstances by means of binoculars or wide-field optical equipment.

"The satellite's angular motion in the zenith will be of the general order of one degree per second, making the satellite a very rapidly moving object for precise observation by visual techniques and also difficult by photographic or photoelectric techniques not especially adapted for the problem. For example, the limiting photographic magnitude of the Baker super-Schmidt meteor cameras (12-inch aperture, 8-inch focal length) is approximately 6.0 for an object moving one degree per second. The 48-inch Schmidt camera of the Palomar Observatory is theoretically about this fast, but probably will reach somewhat fainter. Thus, only the most rapid large-aperture Schmidt cameras can be immediately suitable for observing the satellite. They will be plagued, in practice, by the brightness of the sky during the intermediate twilight periods when the chances of the satellite crossing will be great. The problem imposed by the twilight sky is perhaps best illustrated by the fact that at a zenithal altitude of 200 miles the satellite would lie on the edge of the earth's shadow at the commonly accepted limit of the twilight period when the sun is 18 degrees below the horizon.

"Special devices for following the motion of the satellite will undoubtedly be of great value in making its photography practical with less extreme equipment. Following may be accomplished in a num-

The American Astronomical Society meeting at Rensselaer Polytechnic Institute, Troy, N. Y., November 10, 1955.

KEY TO PHOTOGRAPH

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ber of ways including optical guiding of the telescope (very difficult), mechanized motion of the telescope according to the theoretical motion of the object, or by motion of the film or plate. Oscillatory motions of the instrument, the emulsion, or the light beam may also help.

"Visual observations of the satellite may be useful for acquisition purposes and for measuring the satellite's line of motion across the sky. Visual observations to determine position along the direction of motion will generally not be very precise, because of its extremely rapid motion and the concomitant severe requirement on time determination. . . .

"Precision of measurement across the line of motion may be considerably

greater, however, than that along the line of motion. At the expected distances, each second of arc corresponds to a distance of the order of 10 feet, for example. Hence, accurate observations can provide a type of Sumner line for precise determination of station positions in the case when the satellite orbit is extremely well observed and when it moves in an orbit sufficiently highly inclined that the latitude of the station is numerically smaller than the inclination of the orbit to the earth's equator. . . .

"Let us explore the scientific gains to be expected from observations of such an artificial satellite, regardless of whether it contains scientific equipment and electronic telemetering for sending the observations to the earth's surface. The first problem is clearly to determine the density of the high atmosphere by measuring the perturbations in the orbit due to atmospheric resistance. Reasonably good observations of a satellite (whether primary or secondary) with a low ratio of mass to surface area can yield determinations of mean atmospheric densities with phenomenal precision. Whereas rocket methods for measuring ambient temperature become difficult at densities of the order of 10^{-8} atmospheres or less (10^{-11} grams per cubic centimeter), the satellite method can easily be used to 10^{-5} of this density and, with sufficient time, to much lower values.

"Since the atmospheric density always decreases with altitude, its effect is to produce a maximum resistance near perigee and a minimum resistance near apogee [about 800 miles]. As a consequence, the perigee altitude of the satellite decreases relatively slowly until the eccentricity has been reduced markedly. As the apogee approaches the perigee value, they both decrease with a rapidly accelerating pace until the satellite finally falls through the lower atmosphere.

"For a satellite with a lifetime of the order of a year or a few years, extremely precise measurements of perturbations by the earth can be made. The theory of the perturbations of an earth satellite are classical. Especially applicable are theories by F. R. Moulton, D. Brouwer, and specifically by Spitzer. The equatorial bulge causes a regression of the nodes and a forward motion for the line of apsides, comparable in period and of the order of two months. Spitzer has shown that the lunar and solar perturbations are relatively insignificant for small orbits. The degree to which the distribution of the mass within the earth, particularly higher order terms, can be determined by observations of a satellite close to the surface has not yet been investigated by me.

"Geometrical observations of the satellite will yield an extremely precise determination of the earth's figure and tie together very accurately the geodetic systems of the various continents and islands. Determinations of geodetic positions in three dimensions with respect to the earth's center can be visualized to a precision of the order of 10 feet. Since this precision is about an order of magnitude more accurate than others of the most precise methods, the satellite will clearly open up an entirely new realm of geophysical measurement concerning the distribution of material within the earth.

"The practical problems of ephemerides and prediction for observations of the satellite constitutes a major problem of international interest. The means for handling this problem are being considered by the technical panel on the earth satellite program. It is hoped that a radio beacon can operate continuously from the satellite, particularly in the earlier stages, to provide quick information concerning the satellite's position for the purpose of deriving orbital elements and thereby predictions of position.

"The possibility of physical measuring equipment on the satellite, with telemetering equipment to relay the measurements to the earth, presents an enormous scientific challenge and also a tremendous responsibility to those who will choose and instrument the experiments. What experiments will lead to results of maximum scientific value? Among the types of measurements that may be anticipated are: 1, cosmic rays and high-energy particles; 2, solar corpuscular radiation; 3, micrometeors; 4, solar ultraviolet and X-rays; 5, magnetic field and Störmer ring current; 6, hydrogen in interplanetary space; 7, atomic, ionic, and molecular masses in the ambient air. All of these quantities may correlate with or be physically associated with other quantities measured in the International Geophysical Year, from solar activity to magnetic changes deep within the earth."

Distance of the Radio Source in Sagittarius

The intense radio source at galactic longitude 327°.8, latitude −1°.4, known as Sagittarius A or 1782A, is probably not associated with the galactic center but is considerably nearer to us. This result has been reached by Edward F. McClain, of the Naval Research Laboratory, from a study of how continuous radiation from the source is absorbed by interstellar neutral hydrogen located between the source and us. This absorption takes place at a wave length of 21 centimeters.

Dr. McClain has devised a method for estimating the distance of such a source from the breadth of the absorption, which depends on the spread in velocity of the intervening hydrogen clouds. He assumes the thickness of the hydrogen gas at right angles to the galactic plane to be 240 parsecs. The observed absorption effect for Sagittarius A occurs roughly within the velocity range −10 to +15 kilometers per second. This absorption effect then corresponds to a distance of three or four kiloparsecs, whereas the galactic center is some 8,000 parsecs distant.

This result is in good agreement with a distance of three kiloparsecs derived by Williams and Davies using an independent method. F. T. Haddock and T. P. McCullough, also of the Naval Research Laboratory, have suggested that Sagittarius A is possibly associated with an ionized hydrogen region in a group of hot stars studied by W. Hiltner.

K Stars at Declination −45°

For more than a decade Indiana University astronomer Frank K. Edmondson has been measuring radial velocities of faint stars of spectral class *K*, using northern stars from the proper-motion catalogues of Leander McCormick Observatory. But there has been a gap in the observations, extending over the quarter of the Milky Way that is inaccessible to most Northern Hemisphere observatories.

Therefore, during 1952, 1954, and 1955, Dr. Edmondson carried out observing sessions at McDonald Observatory, located on Mt. Locke in western Texas, at a latitude of 30° 40′ north. Its southern horizon corresponds, therefore, to about declination −60°. Pointing the 82-inch McDonald reflector only 15 degrees above the southern horizon, Dr. Edmondson obtained the spectra of 147 *K* stars of the 11th photographic magnitude at declination −45°.

The observations on this program, for a total of nearly 850 faint *K* stars, are now finished, and the measurements are ready for reduction. The data will give information about the systematic motions of the stars and galactic rotation.

Contour Maps of the Corona

At the High Altitude Observatory station at Climax, Colo., a new 5-inch coronagraph and all-reflection spectrograph have recently gone into daily operation. The instrument is designed for quick changing of focus from one wave length to another, and for rapid translation of the solar image across the spectrograph in automatically controlled steps. The grating is readily rotated, giving a spectral range from ultraviolet into infrared.

D. E. Billings, R. T. Hansen, and Carlos Varsavsky reported on the daily survey of the sun's entire limb at wave lengths 5303 and 6374 angstroms. At each position of bright coronal emission, a sequence of graded-height spectra is taken, representing regions in the solar atmosphere differing in height above its surface by about 5,800 kilometers. The photographs are analyzed by a microphotometer that automatically traces line profiles every 2½ degrees around the limb, and from the resulting data the High Altitude astronomers compile isophotal contour maps of vertical sections in the corona. Thus they obtain, on a routine basis, data for constructing both intensity and temperature models of the corona.

Interstellar Matter

OTTO STRUVE
Leuschner Observatory
University of California

Both bright and dark nebulosity are present in this photograph by John C. Duncan of an S-shaped nebula in Cygnus. The diameter of the circular field is 38.4 minutes of arc. Dr. Duncan first noticed this object on a photograph he made with the 18-inch Palomar Schmidt telescope in 1948. This picture was taken October 1, 1950, with an exposure of 70 minutes on an Eastman 103a-E (red-sensitive) plate with a red Plexiglas filter, using the 36-inch reflector of the Steward Observatory, University of Arizona. South is at the top.

THE MILKY WAY contains a vast amount of finely divided interstellar dust and gas. Most of it is concentrated in clouds, ranging from round, black, compact globules of dust about a tenth or a hundredth of a light-year in size, to enormous chaotic complexes of gas and dust several hundred light-years across, such as those in Orion, Taurus, Cygnus, and Scorpius.

These cosmic clouds are associated with the spiral arms of our galaxy. They are strongly concentrated toward the plane of the Milky Way in a layer about 1,000 light-years in thickness, but extending at least 50 times as far in the plane of symmetry.

In the vicinity of the solar system the hydrogen gas amounts, on the average, to about one atom per cubic centimeter, or 10^{54} atoms per cubic light-year. Since the weight of a hydrogen atom is of the order of 10^{-24} gram, the gas contained in a cubic light-year has a mass of 10^{30} grams. If we could spread out all the stars uniformly in space we would find that the resulting density is of the same order of magnitude. Matter in our spiral arm is pretty evenly divided between the stars and the hydrogen gas.

Gases other than hydrogen are also present, and their atomic abundances closely resemble those found in the sun and in most other stars of the spiral arm population. These gases are so rare in space that we can regard them as impurities—they add very little to the total mass of the medium.

In the vicinity of hot stars the hydrogen gas is almost completely ionized; the ions and electrons move independently of each other through the cloud. When they accidentally collide, they produce the familiar red-green glow of the gaseous nebulae. A single *O*-type star may ionize all hydrogen within a sphere 400 light-years in radius. But a somewhat cooler star, of class *B*0, ionizes the gas to a distance of only 80 light-years. The ionizing action of stars like the sun is so insignificant that they produce no luminous nebulosities visible on direct photographs. The temperature of the ionized hydrogen spheres around hot stars is about 10,000°.

Some faintly luminous hydrogen nebulosities, in Cygnus and Orion for example, are excited not by the radiation of a single very hot star, but rather by the integrated ultraviolet light of many stars embedded in the gas clouds or surrounding them.

There are also many clouds of cold hydrogen. These are located far away from any *O* or *B* stars, and their hydrogen is not ionized. The presence of these clouds of neutral hydrogen was first detected by means of the forbidden hydrogen line at wave length 21 centimeters, which can be observed only with radio telescopes. The temperature of these clouds is of the order of 100°, counted from the absolute zero of temperature at −273° centigrade.

Some cold hydrogen is also present between the spiral arms of the Milky Way, in the central nucleus of the galaxy, and perhaps even in the galaxy's outer spherical halo of old stars and globular clusters. But the density of the atoms in these regions is only one tenth or one hundredth of that in the spiral arms.

When a large hydrogen cloud contains one or more hot stars, the interior volume of hot, ionized gas is surrounded by un-ionized hydrogen, the temperature difference being that of 10,000° and 100°. The result is a tremendous outward pressure at the interface between the hot and cool gas. The hot core expands—essentially by the pressure of the star's radiation—and this pushes the cold envelope outward. Hence, nebulae of this kind expand, often breaking up into smaller clouds which move with velocities of some 5 or 10 kilometers per second.

The atoms in cold regions of interstellar space may combine to form simple molecules, like CH, CH_4 (methane), NH_3 (ammonia), OH_2 (water), and these molecules may stick together to produce small grains of dust or smoke. The gas is highly transparent, but the dust grains are efficient absorbers of radiation. Hence they produce the intense obscuration observed in dark clouds and even in relatively open regions of the Milky Way. The dust particles do not only cut off a part of the light of very distant stars; since they absorb more violet light than red, they cause the transmitted light of the stars to appear redder. From this effect of selective absorption the sizes of

the grains have been found to average about 1/100,000 of a centimeter [but see page 112].

Finally, the transmitted starlight is slightly polarized. The particles are not spherical in shape. They must be needle-like crystals, and they are oriented not at random, but in a preferential direction—at right angles to the lines of interstellar magnetic forces.

In total mass, the dust grains amount to only one or two per cent of all interstellar matter; the rest is mostly hydrogen gas. The space distribution of the grains is similar to that of the gas. Where we observe dense gas concentrations, as in Orion, we also find great accumulations of dust. But the distribution of dust and gas is not identical in every detail. For instance, there is a small luminous nebulosity surrounding the *B*-type star Sigma Scorpii, part of the great complex of dark and bright nebulae in Scorpius and Ophiuchus. The small nebulosity shows hydrogen in emission on one side, while on the other side the glow we see is simply the light of the star reflected by the cloud of dust.

The interstellar clouds, containing about 10 hydrogen atoms per cubic centimeter, have average diameters of 30 light-years and motions of some 5 to 10 kilometers per second. But some very compact clouds may have central densities of 1,000 or even 10,000 atoms per cubic centimeter. And some of the smaller clouds travel through space, in different directions, with velocities of up to 100 kilometers per second. Since many clouds are large, they often collide. This generates heat and causes evaporation of the grains. As a rule, the grains do not have time to grow larger than 10^{-5} centimeter in diameter. Hence, the sizes of the particles are about the same in all clouds.

However, in 1953, at the Cambridge (England) symposium on gas dynamics of cosmic clouds, R. Minkowski remarked, "This picture is certainly an extreme oversimplification." And he went on to say,

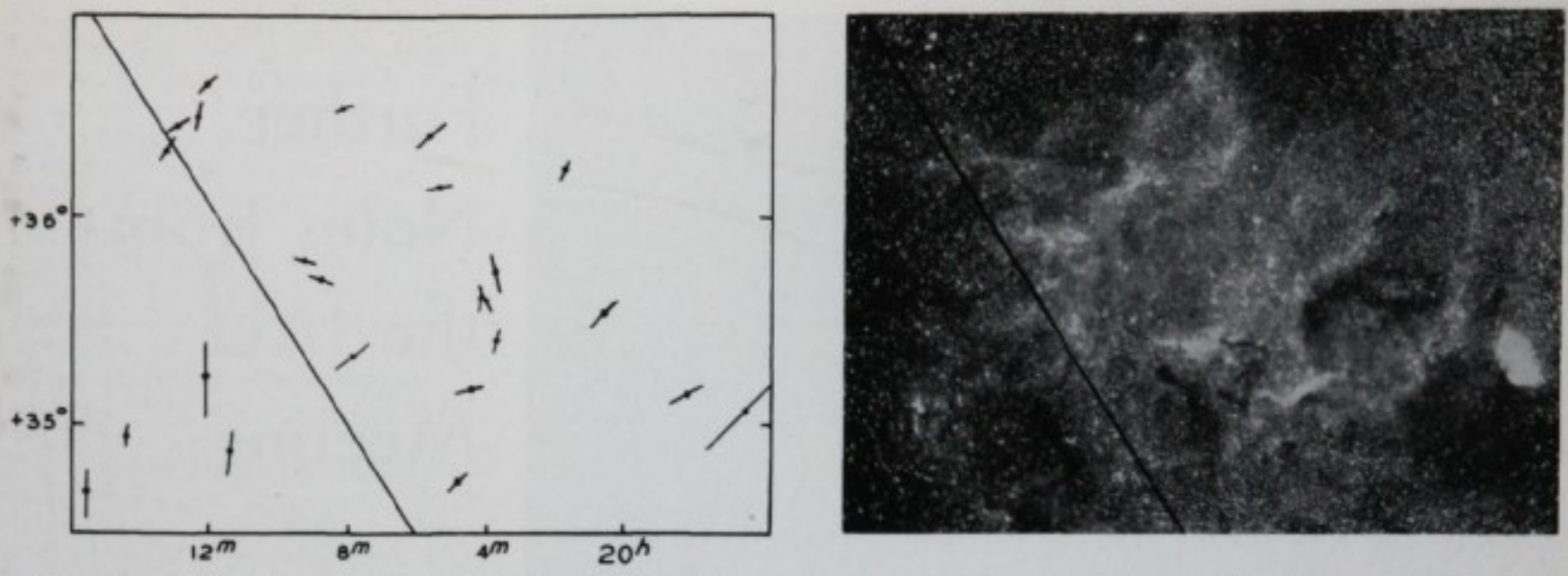
"If one looks at the central Milky Way, it becomes at once obvious that the schematic picture of separate clouds of 10 parsec diameter has little resemblance to reality. An entirely chaotic mass of dark clouds of all possible shapes and sizes appears projected on the background of stars and faint emission nebulosity. The linear scale of the details cannot be assessed easily. Some idea of the scale can be obtained from the bright emission nebulae in the area. The Trifid nebula (NGC 6514) is a typical emission nebula at a distance of 700 parsecs. At this distance the angular diameter of about 30′ corresponds to a linear diameter of about 6 parsecs, somewhat smaller than that of the 'typical' cloud."

Despite the chaotic appearance of the dark and bright galactic nebulosities, there are some interesting tendencies in the forms of these objects. Minkowski has pointed out that the nebulosities in the region of Gamma Cygni "seem to be part of one huge mass, cut in two main parts by heavily obscuring clouds along the galactic equator." On the western side of that nebulous mass, the chaotic appearance "is replaced by filamentary structures and striations" which are many degrees long and which are oriented approximately parallel to the galactic equator.

G. A. Shajn has repeatedly called attention to this tendency for the long filamentary structures in emission nebulosities, and in obscuring clouds, to lie parallel to the galactic equator. Among the latter, one of the most remarkable objects is the dark lane east of Rho Ophiuchi, which extends about 40 minutes of arc wide for more than six degrees and which is oriented at a moderate angle to the galactic equator.

Two important questions arise immediately: Why are so many clouds greatly elongated? And why are they preferen-

In this Crimean Astrophysical Observatory photograph, extending eastward (left) from Rho Ophiuchi are several elongated dark nebulae. The short white lines indicate the direction of interstellar magnetic lines of force as deduced from the polarization of the light of six stars near Rho. The long diagonal line is the direction of a galactic parallel of latitude. The head of the Scorpion is along the right edge of the field, with Antares and M4 above the lower border. Courtesy, G. A. Shajn.



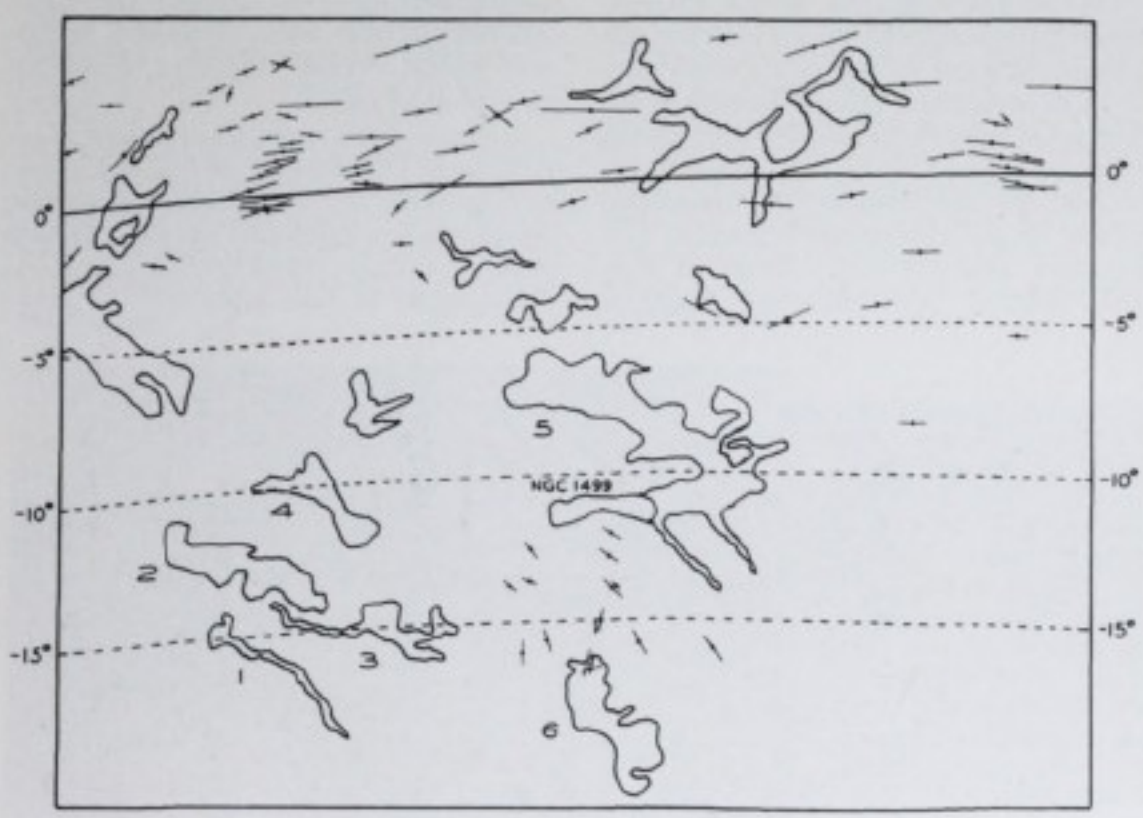
Complex wreaths of emission nebulosity fill this area of three by two degrees in Cygnus, just south of the star 28 Cygni, which is near the top of the field. Here Dr. Shajn compares the orientation of the wisps of nebulosity with polarization observations (left) by W. A. Hiltner. The sloping line marks the galactic equator.

tially oriented parallel to the galactic equator? Shajn shows rather convincingly that the answer cannot be found in the shearing action of galactic rotation. An initially spherical cloud 15 light-years across will be elongated in the plane of the Milky Way by such shearing, but even after 10 million years the longer axis will be only 20 light-years, a relatively insignificant effect! In reality, the lengths of many clouds are 80 or 90 light-years, while their cross sections measure only 15 light-years. The ratio of length to cross section may be six, or even larger.

In order to find a plausible answer to the two questions, Shajn has studied the orientations of many nebulae in different parts of the sky. Near the center line of the Milky Way, both emission nebulae and dark clouds tend to be drawn out parallel to this plane. For example, out of 164 dark clouds there are five times as many making angles between 0° and 30° with the Milky Way as there are from 60° to 90°. That ratio is still larger when we compute the real distribution of the orientations in space, rather than the apparent orientations on the celestial sphere.

Measures of the planes of polarization of transmitted starlight also show that the magnetic lines of force lie preferentially parallel to the plane of the Milky Way. But to connect the two phenomena, Shajn had to find whether, in those regions in which the nebulae make appreciable angles to the Milky Way, the planes of polarization show similar departures.

The chart given below shows this is indeed the case. Shajn has plotted the dark features from the Skalnate Pleso Atlas of the Heavens, and he has entered also the orientations of the magnetic lines of force inferred from the planes of polarization. The mean inclination of the elongated nebulae 1, 2, 3, 4, 5, 6, to the galactic equator is −35°, while in the same region the magnetic lines of force are inclined −41° ± 3°. Thus, it can hardly be doubted that the nebulae are drawn out along the magnetic lines of force.



Dr. Shajn here indicates the relation between dark nebulosities in the Perseus-Taurus region and the polarization observations by W. A. Hiltner and John S. Hall. Near the center is NGC 1499, the California emission nebula. Parallels of galactic latitude are shown.

In order to explain this phenomenon, Shajn makes the reasonable assumption that all nebulae tend to expand, with velocities of the order of 15 kilometers per second. If there were no magnetic forces, a spherical nebula would remain spherical (neglecting the galactic shearing effect), but in one million years its diameter would grow from 15 to 90 light-years, a ratio of six times. The densities, of both hydrogen ions and free electrons, would decrease by 216 times (6^3). The surface brightness of a nebula is proportional to both the ion and electron densities, and to the thickness of the column of gas through which we look. The product of the changes in the densities would be $1/6^6$, while the optical column in the expanded shell would be six times longer than in the original nebula. Hence, in a million years the surface brightness would change by a factor of $1/6^5$, or 1/7,776. Even in 100,000 years the surface brightness would have decreased to 1/32, while the nebula doubled in size. Such spherically expanding nebulae would become invisible in little more than 10,000 years!

But if the magnetic field is sufficiently strong, ionized gas cannot cross the lines of force, and the nebula can only expand along the lines. Our small spherical

(Continued on page 120)

The southern part of the moon, photographed with the Pye television equipment attached to the 12-inch refractor at Dunsink Observatory. The lunar crater Tycho is prominent at the right.

Further Notes from the IAU Meeting

Astronomical Television

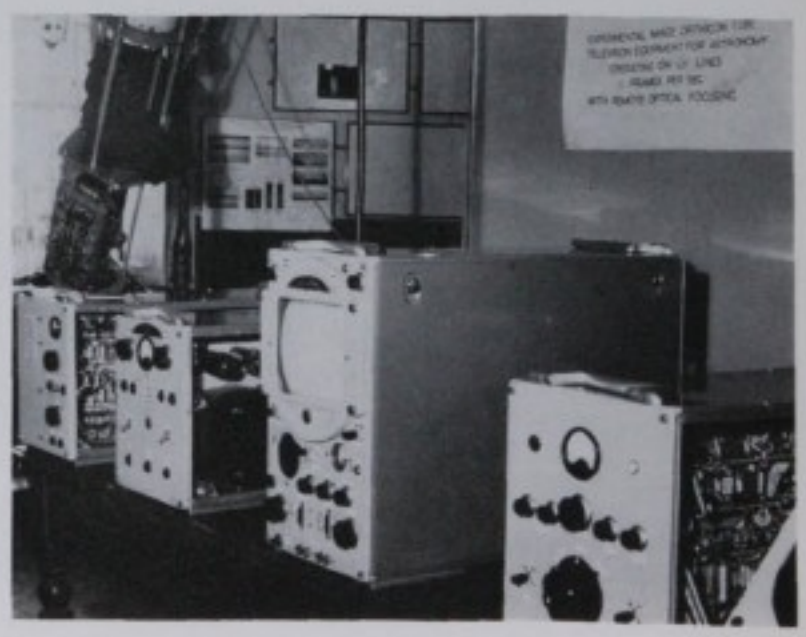
THE next advance in astronomical observing technique may be the electron telescope, in which the light receiver uses a highly sensitive photocathode instead of a photographic plate. This possibility is being chiefly explored by astronomers and electronic engineers in France, Great Britain, and the United States, as told by Otto Struve in *Sky and Telescope* for April, 1955.

The ordinary photoelectric cell, however, can measure an image only by laboriously scanning it point by point, and this makes the process much slower than photographic portrayal for an extended object. In order to take advantage of the high quantum efficiency of a modern photocathode, it is necessary to use a photoelectric method that gives an image directly—to use image converters or television methods. The latter are more complex, but they provide directly a wave form representing the image, whereas the output of an image converter must subsequently be measured, as by a microphotometer.

One of the highlights of the International Astronomical Union's meeting was a demonstration at Dunsink Observatory of an experimental television method for displaying images formed by the 12-inch refractor. The equipment, brought to Ireland for the purpose, was developed jointly by the Cambridge University Observatory and the radio works of Pye, Ltd., located in Cambridge, England. The experiments were begun in 1952, using standard television equipment, by Dr. Peter Fellgett, of Cambridge Observatory, and B. V. Somes-Charlton, of Pye, Ltd. Later, modifications were introduced, for example, to allow storage times longer than the normal television frame times. Recently, a supersensitive image orthicon has been used for the television image tube. This is advantageous for the intensification of very faint images, as the tube incorporates a high-gain (1,000-fold) electron multiplier, and the later addition of two image-intensifier stages has further increased the sensitivity by 100 times.

The accompanying two photographs of the lunar crater Maurolycus show at the left an enlargement from an ordinary photograph, exposure four seconds with the Cambridge 25-inch refractor, and at the right a 1/5-second exposure of the corresponding area on the television screen. Such pictures demonstrated that the exposure times required for planetary and stellar photography can be substantially reduced by feeding the light collected by the telescope into a television system, whose displayed image is then photographed.

Essentially this same method was tried at Lowell Observatory in 1954 for observing Mars, and a television picture of the planet was published on page 77 last month. At Cambridge, for fast planetary photography to take advantage of fleet-



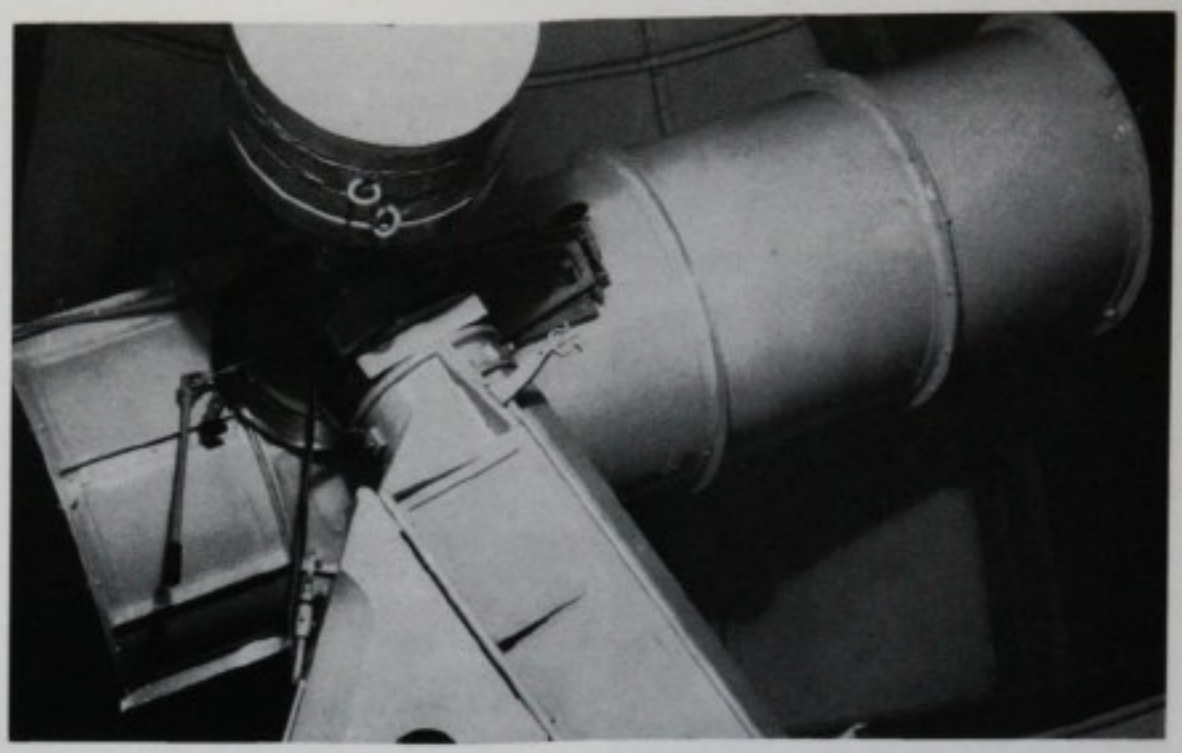
At the left, the Pye television image tube is seen attached to the eye end of the 12-inch Dunsink refractor. But, as the picture at the right shows, the image tube is only a single part of the considerable electronic equipment that was required to carry on the astronomical television experiment. Dunsink Observatory photographs.

ing instants of good seeing, Mr. Somes-Charlton is arranging for the television system to operate sequentially at 100 frames per second (without odd-and-even field interlace) in order to reduce the image tube exposure time.

The accompanying picture of the hydrogen-alpha line in the solar spectrum was made to show the value of television in spectrographic studies of the sun, an application which can be extended to ultraviolet and infrared wave lengths. Stellar spectra can also be reproduced in this same way where sufficient light is available.

During the Dublin meeting, evening skies were mostly unfavorable for the television apparatus demonstration at Dunsink, but at 5 a.m. on the morning of September 4th, through occasional breaks in the cloud cover, several good pictures were obtained, without benefit of color filters to reduce the refractor's chromatic aberration.

A television view, in red hydrogen light, of a prominence on the edge of the sun, made August 12, 1955, with a solar telescope and a Pye picture monitor. The slit of the spectrograph was placed perpendicular to the edge of the sun, above which the prominence protrudes. Below it is the hydrogen-alpha absorption line in the solar spectrum. The original dispersion was 3.36 angstroms per millimeter. Pye, Ltd., photograph.



The 28-inch reflector at Dunsink Observatory is a modified Cassegrainian (with diagonal). It is set on the mounting of the original Grubb 15-inch telescope. For photoelectric measurements of the brightnesses and colors of stars, this instrument is used with a twin-register pulse-counting photoelectric photometer built by Dr. M. J. Smyth. He is seen in the photograph below, taking a reading from the recording dials of the photometer control panel. Dunsink Observatory photographs.

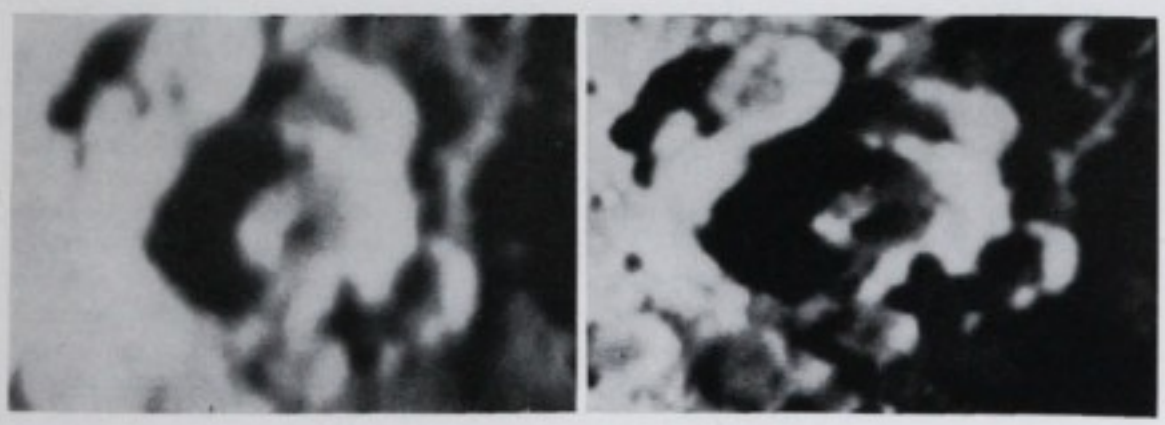
Amateur Observations of Variable Stars

SO BROAD is the field of variable stars that nearly a quarter of all technical astronomical publications today deal with variables in one way or another. The aspects of variable star astronomy discussed at Dublin were so many that only one phase can be touched on here—the role of the amateur observer.

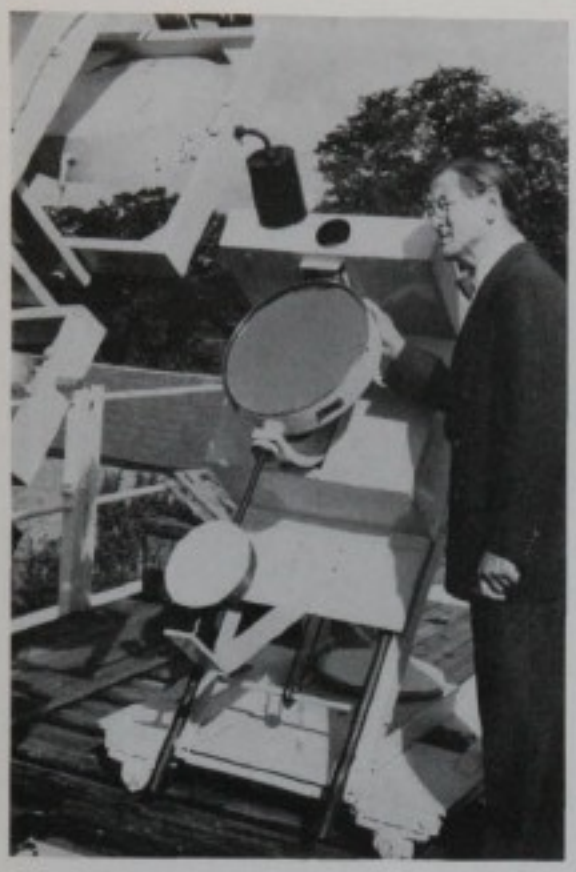
At the meeting of the commission on variable stars, 27, its chairman, B. V. Kukarkin, of Moscow, stressed the value of visual work on variables by amateur observing associations like those in Australia, England, France, Italy, New Zealand, Scandinavia, and the United States. As one instance of the value of their work, professional astronomers who observe the spectra of variable stars often depend on the amateurs' light curves for planning their programs and interpreting the results.

Professor Kukarkin urged that the programs of the various observing groups be more closely co-ordinated to avoid duplication of effort. Very many estimates are made of some well-known long-period variables, while other important stars which are no more difficult to observe suffer neglect. To consider this problem further, Mrs. Margaret W. Mayall, recorder of the American Association of Variable Star Observers, called an informal meeting of representatives of variable star observing groups.

At this meeting it was pointed out that such duplication is sometimes desirable, when climatic conditions in one country may prevent observations for



The lunar crater Maurolycus, photographed April 16, 1953, at Cambridge Observatory. The television picture, on the right, is affected by horizontal expansion caused by the scanning mechanism. The region of this crater may be found on the center picture in this issue. Pye, Ltd., photograph.



Dr. H. A. Bruck, director of Dunsink Observatory and host to the International Astronomical Union meeting, is here seen adjusting the twin coelostat. These 8- and 16-inch mirrors feed sunlight to the solar spectrograph and spectrohelioscope. Dunsink Observatory photograph.

many days in succession; observers of the same star located around the world are therefore desirable.

During the informal session, some valuable suggestions were offered by G. H. Herbig, Lick Observatory, on types of variables for which visual observations are specially desirable. Continual observation is warranted for long-period variables like R Hydrae and R Aquilae, whose periods are changing progressively. Moreover, the long-period stars still provide occasional surprises, such as the unexpected novalike brightening of RR Telescopii in 1944.

Dr. Herbig cited stars of the R Coronae Borealis type as needing watching. These stars are normally bright, temporarily fading at irregular intervals. A third group of objects that should be on more amateur lists is that of the novalike variables, such as Z Andromedae, AX Persei, and CI Cygni. The early-type irregular variables of large range—such as UX Orionis, BN Orionis, and WW Vulpeculae—are little observed despite their importance.

Finally, Dr. Herbig stressed the desirability of more observations of the T Tauri or RW Tauri stars, now realized to be of great significance in problems of the formation of stars. Many of the recently discovered objects in this class are bright enough for convenient observation in amateur telescopes. There are some, like RR Tauri and Y Leporis, whose light varies so rapidly that the co-operation of observers in different geographical longitudes is needed to obtain a coherent light curve.

Armagh Observatory

As part of the meeting at Dublin, some 500 astronomers visited Armagh Observatory in Northern Ireland (see the front cover). This is one of the oldest of the world's active observatories, having been founded in 1790. During its long life the observatory has had only seven directors, of whom the fourth was J. L. E. Dreyer, the Danish-born compiler of the famous *New General Catalogue of Nebulae and Clusters*. His successor was the Rev. W. F. A. Ellison, well known as a telescope maker, and as a pioneer in the amateur telescope making movement in Great Britain; he was the author of *The Amateur's Telescope*.

Recently Armagh Observatory has been modernized and refitted with new instruments. Chief among these is a Schmidt telescope with a 12-inch correcting plate and an 18-inch mirror. This was converted from an old Calver reflector, the funds being made available by the Royal Society. The 10-inch Grubb refractor, established by Dreyer, is used for visual work; it possesses an excellent micrometer, the gift of Sir Howard Grubb. This year a Haffner iris photometer was added to the equipment.

The director at Armagh, Eric Lindsay, is a specialist in galactic structure who studies the southern Milky Way on photographs taken with the Baker-Schmidt telescope at Bloemfontein, South Africa. The operation of this instrument is shared by six observatories, including Armagh and Dunsink.

Dr. E. J. Opik, of Armagh Observatory, here stands beside his vibrating meteor camera. The motor at the bottom of the pier gives the camera an oscillatory motion while the plate is being exposed on the sky.

Meteor studies, both observational and theoretical, form a major part of the work at Armagh. Here E. J. Opik photographs meteors with a vibrating camera, so that their velocities can be measured from their looped trails. A second camera, 20 miles to the northeast, operates simultaneously for the determination of the heights of meteors caught by both cameras. Dr. Opik is editor of the *Irish Astronomical Journal*, published at Armagh by the Irish Astronomical Society for both amateurs and professionals.

INTERSTELLAR MATTER

(Continued from page 117)

nebula 15 light-years in diameter will, after a million years, resemble a cylinder whose cross section is still the same as before, 15 light-years. But its length will now be 90 light-years. The two densities, of the ions and the free electrons, will both have decreased merely to 1/6, and the surface brightness by their product, 1/36. Compare this with the factor 1/7,776 for the spherical expansion after a million years.

At the top of page 117 is shown a region just east of Eta Cygni, together with a plot of the orientations of the magnetic force lines. Again the agreement is good. Apparently both the bright ionized and dark un-ionized clouds are drawn out along the lines of force. For the emission nebulae this is understandable; their electrical conductivity is high and their behavior resembles that of an iron ball in a magnetic field. If the field is weak, the ball would carry the magnetic lines with it. But in a strong field, the ball experiences much resistance against motion across the lines—it adjusts its motion to follow the lines of force.

But even the dark hydrogen gas clouds contain ionized atoms of elements other than hydrogen. Their ions and electrons produce a sufficient amount of electrical conductivity. Moreover, the dust grains collect small electrical charges on their surfaces. Thus, the dark clouds as well as the bright ones are constrained to orientations along the force lines of the interstellar magnetic field.

Shajn argues that since we observe many bright nebulae they must be fairly old, on the average. If their expansion were always to proceed with spherical symmetry, the emission nebulae would fade so rapidly from sight that we should observe only a small number of them at any given time. Nonspherical expansion—chiefly into very elongated filaments—can explain the fact that so many bright nebulae are seen at present.

NEWS NOTES

By Dorrit Hoffleit

THE ROTATION OF PLUTO

Since Pluto, the outermost planet in the solar system, appears nearly like a star in even the largest telescopes, its rotation period cannot be found from direct observation of surface features. However, if its surface has light and dark markings, variations in the planet's apparent brightness may indicate the period of its rotation. At Lowell Observatory, Merle F. Walker and Robert Hardie have found such a variation by means of photoelectric measurements with the 42-inch reflector.

Combining their 1955 data with a few earlier photoelectric observations by Dr. Walker at Mount Wilson in 1954, and by G. P. Kuiper with the 82-inch McDonald reflector in 1953, they obtained 6.390 earth days as the probable period of Pluto's rotation.

The change in brightness during Pluto's day is 0.1 magnitude, about the same as that of Mars for one rotation; this suggests that Pluto is at present seen more nearly with its equator toward the earth than pole-on. The possibility of a very short rotation period for the planet was ruled out by Lowell observations covering up to seven hours on the same night without appreciable brightness change.

This investigation was reported in the August *Publications* of the Astronomical Society of the Pacific.

METEOR PHOTOGRAPHY ON RECORDING PAPER

Two short notes in the *Irish Astronomical Journal* call attention to the value of paper negatives for the photography of meteors. During searches for asteroids, D. A. Campbell discovered the efficiency for this purpose of Kodak R. P. 30 High Speed Normal Recording Paper (originally designed for recording the fast-moving light spot on a cathode-ray oscilloscope). Two meteor trails, photographed by Mr. Campbell with an Ektar f/2.9 lens, one of the 2nd magnitude and the other of the 3rd, have been analyzed by Dr. E. J. Opik, of Armagh Observatory.

He finds the quality of the images excellent, and there is practically no background fog. The success of the paper negatives comes from their unusually great reciprocity failure; they are extremely sensitive to short exposures of bright light, and insensitive to long exposures on faint objects like the sky background. In fact, to obtain equally dense images, a 2-, 3-, or 4-fold increase in the brightness of an object must be balanced by decreasing the exposure 16, 81, or 256 times (instead of only 2, 3, 4 times, as for ordinary plates without reciprocity failure). Thus the length of exposure matters very little with the paper negatives, compared with the intensity of light.

This is ideal in meteor photography, where the greatest obstacle has been the background fogging of long-exposure plates. In solar work the paper negatives should also prove advantageous. For ordinary stellar photography, however, where the light sources are relatively weak, there would be no advantage.

RADIO WAVES 8,000 MILES UP

Lightning flashes produce radio waves that bounce back and forth between the Northern and Southern Hemispheres of the earth, traveling along the lines of magnetic force and reaching distances as high as 8,000 miles above the earth's surface. Evidence to this effect was presented at the November meeting of the National Academy of Sciences by M. G. Morgan, Dartmouth College, and G. McK. Allcock, Dominion Physical Laboratory, Wellington, N. Z., in confirmation of a theory first proposed by L. R. O. Storey, an English radio engineer.

They reported the results of an international experiment in which simultaneous tape recordings were made of low-frequency radio waves received at radio observatories in Unalaska, Aleutian Islands, and New Zealand, 6,800 miles apart. These stations have the same geomagnetic longitude and corresponding geomagnetic latitudes. H. W. Curtis, of the Thayer School, Unalaska, and Mr. Allcock made the recordings.

"When a lightning flash occurs," said Dr. Morgan, "it is like hitting the atmosphere with a hammer, and the impact produces many kinds of radiation, from visible light down through radio waves of audio frequency. In fact, the energy peak is at about 10 kilocycles per second, in the top octave of the audio frequency range."

From a flash of lightning near the northern station at Unalaska, the radio waves follow the earth's magnetic lines of force, according to the Storey theory, to the Southern Hemisphere, where the New Zealand station records it as a drawn-out swish descending in pitch. This is then reflected by the earth back to the first observer, who for the first time hears the swish, even more elongated in time. The duration of the swish is caused by the lesser velocity of the waves of lower frequency, which lag farther and farther behind the faster-moving waves of higher pitch.

Observations to test the theory were begun on August 23, 1955. Five days later, during a four-minute period, the first good activity occurred. The times of occurrence were confirmed by cable messages between Unalaska and New Zealand. Trains of radio swishes had coursed back and forth far above the Pacific from atmospheric discharges both in the Northern and Southern Hemispheres.

To produce the gradual bending of the radio waves along the earth's magnetic field, as well as the slower velocity of the lower frequencies, Dr. Storey's theory requires a density of at least 400 free electrons per cubic centimeter along the path. This is the first indication of such a high particle concentration 8,000 miles in space above the earth's surface.

AIR FORCE ACADEMY TO HAVE PLANETARIUM

The importance of celestial navigation is indicated by its fundamental place in the curriculum of the Air Force Academy recently inaugurated at Lowry Air Force Base in Colorado. For this institution, a large Spitz planetarium (Model B) is already under construction, to be installed in a special building on the permanent site of the academy at Colorado Springs.

The star projector will use both standard and specially designed devices for navigation training. The faculty of the academy is adapting its syllabus to utilize planetarium demonstrations in teaching star identification and celestial co-ordinates. Problems of polar navigation can be particularly well treated in a planetarium, where a trip to the poles of the earth requires only a few minutes.

This is the second large Spitz projector to be built, and the first to be installed in the United States. The first Model B is in operation at the municipal planetarium in Montevideo, Uruguay (see *Sky and Telescope*, July, 1954, page 292). The Air Force Academy expects to conduct popular planetarium lectures on a regular schedule, as one of its public service activities; for these the attendance should be good, as this will then be the only major planetarium between Chicago and the West Coast.

IN THE CURRENT JOURNALS

ON THE MARTIAN SURFACE FEATURES, by Gerard P. Kuiper, *Publications*, Astronomical Society of the Pacific, October, 1955. "The controversy is by no means new. It started in the 1890's when Schiaparelli had published his system of single and double canals, and Barnard, one of the most acute observers of all time, at the Lick Observatory with a telescope of twice the aperture and almost certainly with better seeing, could not confirm it."

ISOTOPES IN ASTRONOMY, by R. H. Garstang, *Journal* of the British Astronomical Association, October, 1955. "We shall be concerned with naturally occurring isotopes, whether stable or not, and we shall not consider in detail the many hundreds of isotopes which have been produced artificially in nuclear physics laboratories and which are of little cosmic interest."

☆ ☆ *SKY AND TEACHER* ☆ ☆

Sponsored by the
Teachers' Committee of the American Astronomical Society

THE FIRST COURSE IN ASTRONOMY

SIR JOHN HERSCHEL in the fourth edition (1851) of his textbook on general astronomy devoted almost the whole space to a consideration of the solar system. A very few pages told the student about what we now call astrophysics. That edition of Sir John's book appeared shortly before the discovery of the laws of the spectroscope. These laws, especially when combined with photography, have brought about a revolution in astronomy. The great majority of our research today deals with the nature and description of stars, nebulae, interstellar gases, and even of other galaxies which were undreamed of in Sir John's day.

An increasing proportion of the material in textbooks used for a first course in astronomy has been an exposition of this "new astronomy," as Langley called it. The writer of a text must choose carefully how much space is devoted to the older fraction of our science and how much to that which has been created during the last century.

In a recent review of the fifth edition of J. C. Duncan's *Astronomy* (page 421 of the August, 1955, *Sky and Telescope*), the text was in general praised but received one criticism by the reviewer. He complained that too much of the book concerned the solar system. Duncan used 264 pages for the old astronomy and 210 for the new. This follows quite well the practice in other recent textbooks. At first thought the criticism would appear to be justified. Less than half the book concerns the part of astronomy in which most of today's research is being done.

Before passing judgment on the proper proportioning of material, it is necessary that we consider who the students are, their purpose in taking the course in astronomy, and the amount of contact which they will have in later life with the different parts of the science. Many of the students in a beginning course are enrolled in astronomy rather than physics, chemistry, or geology, for the mere purpose of fulfilling the science requirement for graduation. They are interested primarily in other subjects—economics, psychology, literature, perhaps medicine, or engineering. Another large fraction consists of students who wish a general cultural knowledge, so that they may understand a little more of their relationship to the universe. A small part of the class is interested in physics, chemistry, geology, or meteorology as a profession. They need astronomy because of its direct relationship to their lifework. A much smaller number of the students desire to make astronomy itself their profession or at least to follow it closely as a hobby throughout their lives. Usually a class has none of this last group, and out of a hundred students who are enrolled, perhaps only two or three are of the preceding one. It is rather necessary that the course, therefore, consider the needs of more than 90 per cent of the class.

Much of the general course must be used to answer those questions which commonly are asked by the public. Those of us whose professional work has brought them into intimate contact with the public should be able to form a fairly accurate judgment concerning this interest.

At the Griffith Observatory we have found that the moon is to our visitors by far the most interesting of all celestial objects. This interest has caused us to schedule the moon, whenever available, as the object to be observed by the public through our telescopes. The public is very much interested in the relationship of the moon to the earth, in its size, distance, atmospheric condition, temperature, lack of water, and in possible future use of the moon by man. No other object, even the planet Mars, creates this interest. Rather strangely, many more questions are asked about the moon than about the sun.

Next in popular interest are the planets. When Saturn and Jupiter are in good position, they must be the first substitutes for the moon, except at such times as Mars is well situated for observation of its markings. The questions asked about these objects are many and extremely varied. The public wishes to know the possibility of life on the planets. Merely to tell them that the planets are not capable of supporting life is insufficient, and it is necessary to describe in detail the reasons that we could not live a normal life on any other planet.

A naked-eye comet also attracts a great deal of public attention. The same is true of a shower of meteors. Many people who have no real knowledge of astronomy will, in August, stay up all night long to observe the little streaks of light from Perseus.

Questions concerning the nature of stars, their distances, temperatures, masses, and organization into clusters and galaxies are comparatively few. The sky, which to the unaided eye seems unchanging, does not intrigue them. As soon as they have learned that the stars are, in general, millions of times as far away as are the planets, they lose interest. The beginning astronomy course must satisfy the curiosity of the public and of the students.

During the last dozen years there has been a very rapidly increasing interest in the subject of space travel. People know that a great deal of research is being devoted to rockets, to artificial satellites, and to possible early journeys to the moon. Hundreds of times I have been asked the question, "Do you think that man will travel to the moon during my lifetime?"

In one of the planetarium shows, I have illustrated the distance to the nearest star by stating that if we had some "Buck Rogers fuel" to make it possible for us to journey as far as we might wish, and if we should travel at such a speed that we could reach the moon in 24 hours, it would require months to travel to even the nearest of the planets. The audience still is interested in a reference to the possibilities of such travel, even when it is made explicit that no scientist today would be willing to make any definite prediction of it. However, when they are told that at that speed it would require 300,000 years to travel to the very nearest of the stars and that 10,000 generations of men would need to make their home on the ship, usually there is a little laugh from the audience and they have lost interest in contemplation of such a journey. To them the stars are so far away that the organization of our own galaxy is a matter of only minor concern. Other galaxies than ours appear almost as the unrealities of a dream.

If we attempted to teach them about stellar astronomy, and gave very little attention to the nearby objects, there would be few students. There is something in the nature of all of us that makes those things which are near at hand seem very important. It would appear to me from these experiences, both in teaching university classes for a quarter of a century and in dealing directly with the public for 20 years, that beginning courses in college or university must be devoted primarily to these nearby objects. While he pursues such a beginning course, the abler student may very well decide that he wishes to know more about the distant universe. He may some time be converted to the thought that his life should be occupied with the study of astronomy.

Today, when so much of what a student learns is technical information concerning a restricted field, we are in great danger of developing a race of brainy but narrow specialists. Such men can become dangerous to our society. A broad knowledge of everything that affects the human race is perhaps the first requisite of an education. Later a man may specialize.

CORRECTION

In this department for November, 1955, page 20, center column, Indiana University and Ohio State University should have been included among the institutions that have granted one or more Ph.D. degrees in astronomy over the past 15 years. These names were inadvertently omitted by the editor from the listing in Dr. Wyatt's original manuscript.

A beginning astronomy course must satisfy the demands of a liberal education. After a student has passed that successfully, he will always take a beginning course in astrophysics if astronomy has attracted him. He will take such a course even if he is in that minority who today wish to specialize in celestial mechanics or to carry on research connected primarily with the solar system. In that introductory astrophysics course, his only reference to the solar system will be the consideration of the sun as a star, not as the beneficent body which makes possible life on our tiny earth.

Two hundred pages on stellar astronomy in a modern text would seem ample for the perusal of the student whose interest lies in almost nonrelated fields.

DINSMORE ALTER
Griffith Observatory
Los Angeles 27, Calif.

Amateur Astronomers

PALO ALTO, CALIF.

A highlight of the Peninsula Astronomical Society's star party on September 9, 1955, was a 6-inch reflector, designed and built by Robert T. Jones. The telescope is a reflector-corrector type, similar to the Baker instrument at Dyer Observatory in Nashville, Tenn. (*Sky and Telescope*, January, 1954), and has a spherical primary mirror of f/4.

A novel feature is that the doublet corrector lens inside focus serves the function of a Barlow lens in addition to correcting the spherical aberration and coma of the primary. The result is a compact instrument having an optical performance equal to that of a long-focus Newtonian.

Nine other telescopes, ranging from a 2.4-inch refractor to a 12-inch reflector, were also used for observing at the star party.

BURLINGTON, VERMONT

A small but active organization is meeting weekly on Friday or Saturday evenings in Burlington; on clear meeting nights they observe from a point about two miles out of the city, and on cloudy nights they meet at members' homes for a lecture followed by discussion.

The Burlington Astronomical Society has access to four small instruments and two 6-inch reflectors. Several variable stars are kept under observation and their light curves plotted, and double stars within reach of the society's instruments are being observed.

Interested adults and teenagers may get in touch with Richard Chiott, 149 Lyman Ave., Burlington, Vt. Thomas S. Phillips is club secretary.

FARMINGDALE, LONG ISLAND

The Long Island Observers Association has recently rented a three-room bungalow with a large back yard that offers an ideal location for the society's 12½-inch reflector. A concrete pier has been poured and the mount set into place. A darkroom and workshop facilities are planned for the future.

In existence for two years, the group had previously met at private houses, but since acquiring its new home is launching a drive for members. Membership is open to any genuinely interested adults who live within traveling distance of the society headquarters.

Meetings are held at 369 Staples St., Farmingdale, every Wednesday evening at 8 o'clock. Lectures by members are given every other week, with observation and stellar photography on the alternate meeting nights. Correspondence may be addressed to John Tosto, 369 Staples St., Farmingdale, N. Y.

DENVER, COLO.

The Denver Astronomical Society is now meeting in the Planetarium Room of the Museum of Natural History at City Park, in Denver. A new Spitz A planetarium has been installed at that location. It will be operated by members of the Denver Astronomical Society in conjunction with the museum.

THIS MONTH'S MEETINGS

Cambridge, Mass.: Bond Astronomical Club, 8 p.m., Harvard College Observatory. Jan. 5, Miss Margaret Harwood, Maria Mitchell Observatory.

Cleveland, Ohio: Cleveland Astronomical Society, 8 p.m., Warner and Swasey Observatory. Jan. 20, Dr. Fred L. Whipple, Harvard College Observatory, "Comets, Meteors and Rainfall."

Dallas, Tex.: Texas Astronomical Society, 8 p.m., Lone Star Gas Co. auditorium. Jan. 23, Ted F. Gangl, "How Astronomers Do It."

Denver, Colo.: Denver Astronomical Society, 8 p.m., Museum of Natural History. Jan. 13, Charles Hansen, "Selenography." Jan. 27, Dr. George Loef, "Terrestrial Applications of Solar Energy."

Geneva, Ill.: Fox Valley Astronomical Society, 8 p.m., City Hall. Jan. 10, Berlyn Pierce, "A Flying Trip Around Planet Earth."

New York, N. Y.: Amateur Astronomers Association, 8 p.m., American Museum of Natural History. Jan. 4, Willy Ley, "Man-Made Moons."

Washington, D. C.: National Capital Astronomers, 8:15 p.m., Commerce Department auditorium. Jan. 7, motion pictures.

Complete Your Astronomy Library

THE HISTORY OF THE TELESCOPE

by Henry C. King

The first book to tell the complete story of the evolution of the telescope from early, crude instruments to today's giants, this is recommended to each telescope user or maker, and to everyone interested in how the universe is explored. 456 pages; 103 halftones, 41 drawings both old and new, plus 52 diagrams. Extensive list of references with each chapter.

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THE STORY OF COSMIC RAYS, by Dr. W. F. G. Swann, Bartol Research Foundation. **75c**

RELATIVITY AND ITS ASTRONOMICAL IMPLICATIONS, by Dr. Philipp Frank, Harvard University. **50c**

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SKY PUBLISHING CORPORATION
Harvard Observatory, Cambridge 38, Mass.

Reprinted from the Questar booklet. More will follow in succeeding advertisements. The entire booklet is available upon request.

DISTINCTIVE FEATURES

If people exclaim at Questar's handsome appearance, that is because it is designed simply and in the tradition of functional utility. Conceived as an instrument for quick, convenient use, it becomes naturally an object for adornment of desk or table. Its color scheme was kept to deep blue and silver with that in mind. Its metals are honestly engine-turned, in variety of texture and polish.

The gem-like depth of color in Questar's patented star chart and moon map is due to the surface treatment of the metal. These maps, like the large circle, and name plates, are anodized by the electrolytic process which changes the surface of the polished metal into a layer of clear, hard, transparent aluminum oxide, a kind of corundum or sapphire. This protective coating has sub-microscopic pores which accept translucent dyes. The metal is engraved by etching through the anodized surface, and the sunken areas or lines are filled with colored enamels.

Some 340 stars are shown in six sizes to indicate stars larger than the fifth magnitude. The three brightest stars of each constellation are designated by their respective Greek letters. Turning the star chart, to match the earth's rotation, reveals the constellations as they rise, while hiding others as they sink below the horizon. Thus the stars on the other side of the chart correspond to those hidden by the earth. The chart gives accurate positions by hour angle or right ascension and in degrees of declination.

No longer need the observer hold complex star charts at arm's length overhead and face in various directions. Questar's chart takes the place of twelve because its rotating feature eliminates the need for a separate chart for each month. In use, Questar is simply pointed south, whereupon the observer, while comfortably seated, may identify objects by comparison with the chart. The amount of data, its scales and color contrast, have been carefully chosen for maximum readability in dim light. Because the planets move, they, of course, cannot be shown upon the chart.

The star chart slips forward to become a dewcap, guarding the front lens against fogging on those moist nights when glass or metal objects, like automobiles for example, radiate their heat and become covered with dew. Under the star chart is a large map of the moon sheathing Questar's tube. All parts of the lunar chart can be examined because the whole telescope tube is rotatable about its axis in the mounting. The eyepiece may be inclined at will, a feature of the greatest convenience in so versatile an instrument.

The barrel is supported wholly at its rear closure by Questar's patented double-U form of fork mounting. One side arm carries the declination slow motion and the other the clamp in declination. The knobs are of two sizes for recognition by feel in the dark, and are hollowed for lightness.

An important innovation is the patented Questar method of mounting the primary mirror on a thimble passing through its perforated center, with plastic shims to keep the glass away from heat-conducting metal. Aside from this support, the mirror is free-standing in air, with consequent mechanical and thermal stability. The long thimble is dry-lubricated, and free to slide along a stainless steel tube, permitting Questar to focus from infinity to the unheard-of short distance of only 7 feet, by moving the thimble and mirror only three-quarters of an inch. Without this ingenious method of internal focussing, we should be obliged to move the eyepiece through a distance of several feet to achieve a similar range.

Another unique innovation is the built-in finder, which projects a clear, sharp, wide-field low-power view into the single fixed eyepiece whenever the main erecting prism is thrust aside by its actuating lever. Thus a finger-flick at any time brings either system's image to the eyepiece. The user never has to grope in the dark for a finder eyepiece and stand practically on his head to use it. At choice, or for the most exacting work, the eyepiece may be used without the erecting prism, in the main optical axis. In this form Questar is sharpest, and the image is inverted in the conventional astronomical manner.

Among the vital refinements built into Questar that transform long hours of observing from drudgery into relaxed pleasure are the rotary controls and finger-flick levers. Slow motion knobs are completely without backlash, and are designed to work for a century without adjustment. The rotary focussing knob runs in nylon threads, and indicates the point of focus by its own position.

Questar's two small levers both actuate and indicate in darkness by the user's sense of touch. The side lever at the right controls the prism, as previously mentioned. The top lever causes an achromatic negative lens to swing into place which doubles eyepiece power when desired. Those who have tried to squint through the tiny lenses of conventional high-power eyepieces will especially appreciate this modern amplifying lens, which extends Questar's effective focal length from 42 to 84 inches—a full seven feet—permitting use of the superior larger eyepieces, whose higher eye-points make them more comfortable to use, particularly by those who wear eyeglasses.

Thus, two more innovations result from Questar's basic concept of merging telescope and accessory, of the finger-tip control of auxiliary optical elements built right into the instrument—Questar has two focal lengths, and each eyepiece has three powers instead of only one.

All these built-in features that set Questar apart are genuine advances in conception and design, calculated to make the use of the instrument an unfailing pleasure.

Many advanced engineering features are not visible to the eye, such as the lavish use of nylon bearing surfaces for the finest, smoothest turning, and to insure that no lubrication should be required for periods of many years. Not obvious at first sight is the system of convenient and safe clutches for quick motion. Not evident at once is the doubly-sealed gear train of the synchronous electric drive, perhaps the simplest ever built into any telescope. It is so devised that once started, there is no lost motion at all throughout repeated settings. The sealed oil-filled motor is the finest available and incorporates a special winding and a special non-magnetic internal shield to eliminate heat. It runs on 60 cycle 115 volt alternating current.

To insure against corrosion, Questar's fastenings are of stainless steel, the strongest and most costly engine turned screws procurable being used.

To demonstrate Questar, one need not wait for night or clear skies. The perfect clarity and enormous magnification of the telescope may be shown anywhere at any time, even in the smallest of rooms. We need only make sure that the test objects are extremely well illuminated, so that the image does not become too dim with enlargement. The solar filter may be demonstrated on a white hot lamp filament just a few feet away.

It is very rewarding to show Questar to the old-timers, the real optical experts, and feel their pleasure. Mr. A. G. Ingalls, who as an editor of the *Scientific American*, is the dean and patron saint of amateur astronomers and who has recently had a crater on the moon named in his honor, said this: "Questar is a little gem, and you know very well I never say such things lightly."

TO BE CONTINUED

HOW TO TELL
WHETHER YOU NEED A QUESTAR

If your telescope is too much trouble to set up and take down—you need the always-ready Questar.

If you can't take it with you everywhere—you need the truly portable Questar.

If you live in an apartment — you need the window-sill-size Questar.

If your wife is saying "Get that contraption out of here!"— you need the easy-storing Questar.

* * *

If you are tired of refractors' rainbows—you need the color-free Questar.

If your reflector is always out of adjustment—you need the permanently aligned Questar.

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* * *

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If you haven't automatic following — you need the smooth, electric Questar.

* * *

If you've finally had about enough of instruments with long shaky tubes — you need the short, rock-steady Questar.

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QUESTAR CORPORATION
NEW HOPE, PENNSYLVANIA

Questar

Graphic Time Table of the Heavens — 1956

ON THE FOLLOWING pages is a chart that is a condensed and simple almanac, giving the rising and setting times of the sun, moon, and brighter planets, and much other useful astronomical information. This Graphic Time Table is published annually by the Maryland Academy of Sciences, through whose courtesy it is reproduced here for the 15th year. Separate copies may be obtained from the Maryland Academy of Sciences, Enoch Pratt Library Building, 400 Cathedral St., Baltimore 1, Md., for 25¢ each; on orders of 20 or more the price is 15¢ each. Large wall charts, 40 by 27 inches, are $1.00.

How to Use the Graphic Time Table

Across the top of the chart are marked the hours from 4 p.m. to 8 a.m.; the days of the year run down the chart. Thus any event, like a particular sunset, can be indicated by a point on the chart. All such points are connected by a curve, and the time of sunset, for example, on any date in 1956 can be read from this curve, by following the horizontal line for the date to the sunset curve.

In this way the Graphic Time Table gives the rising and setting times of the sun and moon and the planets Mercury, Venus, Mars, Jupiter, and Saturn; the duration of twilight; and the times when certain stars and other interesting objects transit, that is, cross the meridian. The moon's phases are also indicated.

Small numbers at the left give the Julian day number. These numbers are a consecutive count of the days, beginning in 4713 B.C., so January 1, 1956, is JD 2,435,474. Julian days offer a simple way to find the interval between two dates by a single subtraction, and they are widely used by astronomers, particularly in variable star work. The Julian day number changes at Greenwich noon, or 6 a.m., Central standard time.

Along the midnight line are Roman numerals that indicate the sidereal time at midnight, in other words, the right ascension of a star then on the meridian at the date in question. Running along the midnight line and crossing it is the curve for the equation of time, which shows how much the sun is fast if the curve is to the left of the midnight line, and how much the sun is slow if the curve is to the right of the line. When the sun is fast, it arrives at the meridian before 12 o'clock noon, by the amount shown. In other words, this curve indicates the local mean solar time for the moment at which a properly adjusted sundial would indicate noon.

Small black circles show moonset for the first half of each lunar month, and small open circles, moonrise from full to new moon. At longitude 75° west, the moon will rise about two minutes earlier than these times; at longitude 120° west, about four minutes later. Also plotted for the moon each day are little marks or "ticks," placed at the corresponding times for moonrise and moonset at the earth's equator; each tick has a horizontal bar pointing toward the time at 40° north, where the moon open or black circle is located. These marks aid interpolation for latitudes intermediate between the equator and 40° north, and may be used for cautious extrapolation to more northerly latitudes.

The scale at the right is for finding rising or setting times of other objects. Set dividers or a strip of paper from the index at the center of the scale to the object's declination, north or south (which must be known), and in the direction desired for either rising or setting. Measure this same distance along the midnight line of the chart beginning at the proper right ascension indicated by the Roman numerals. Should this end point fall outside the chart, add to or subtract from the right ascension 12 hours and reset the dividers using the end of the scale rather than the center index. Through the point established, draw a line parallel to the vernal equinox line on the chart. This will show the time of the rising or setting of the object.

The Events of a Single Night

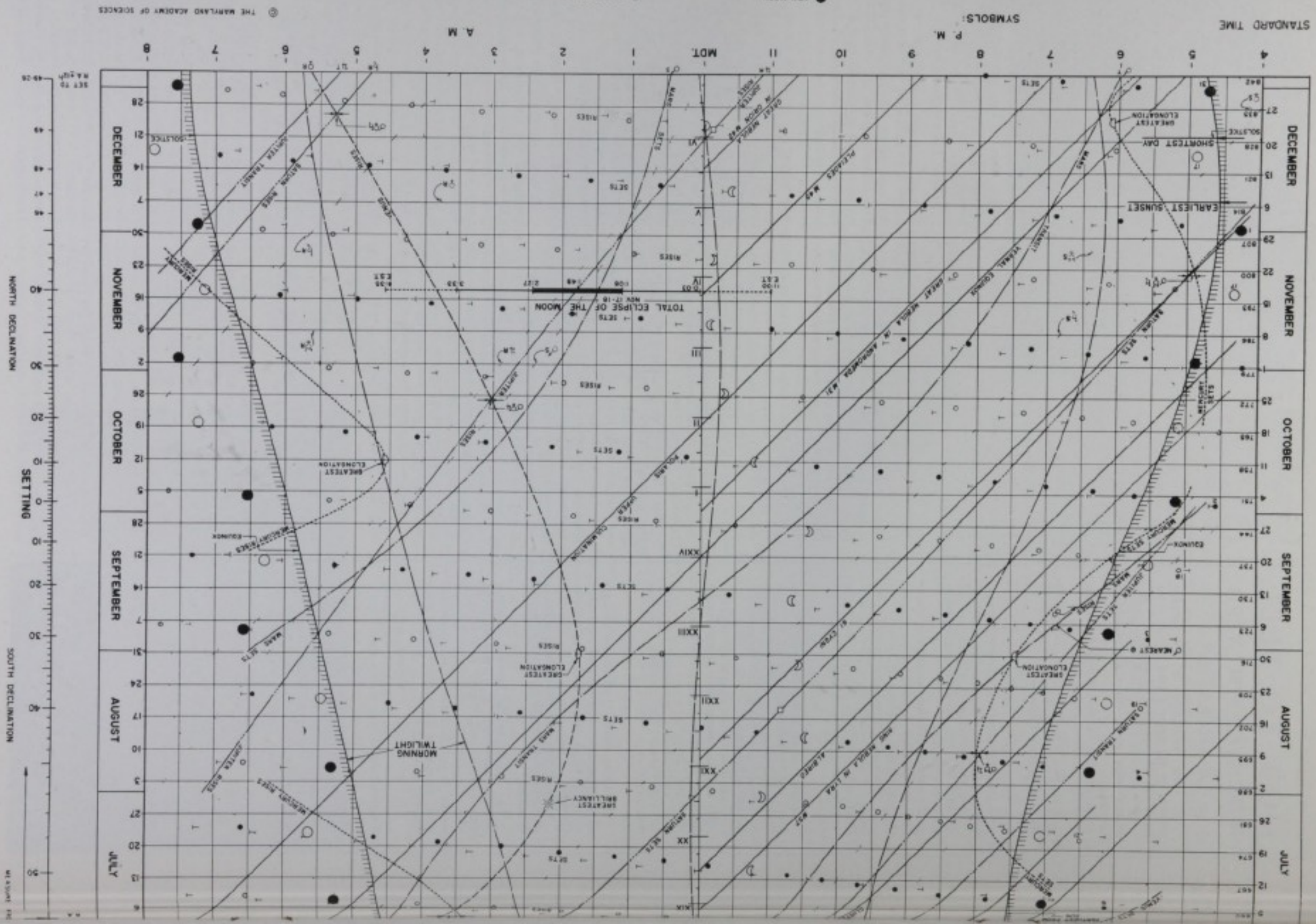
As an example, consider the night of January 5-6 by following the horizontal line for that date across the chart from left to right. The Julian day number is 2,435,478. Sunset occurs at 4:48 p.m., and at 4:59 the vernal equinox transits—marking 0^h local sidereal time. Mercury sets at 6:10, shortly before evening twilight ends at 6:25. The upper culmination or transit of Polaris is at 6:56; Venus sets at 7:18 and Jupiter rises at 8:30; the Pleiades transit at 8:47, followed by the transits of the Orion nebula at 10:33 and of Sirius at 11:45. The sidereal time at midnight is $6^h\ 58^m$; and the curve for the equation of time shows that the sun is slow, and will not reach the meridian until five minutes after 12 o'clock noon, local time, on January 6th. Moonrise is at 12:42 a.m.; Jupiter transits at 3:15, while Mars and Saturn rise at 3:33 and 3:51, respectively. Morning twilight begins at 5:44. Polaris' lower transit is at 6:54, and sunrise is at 7:22 a.m.

How to Correct for Your Position

As in all almanacs, the times of rising and setting of the sun, moon, and planets are strictly correct for only one point on the earth's surface—for this chart, latitude 40° north and longitude 90° west. The observer may easily correct for his own position.

Correction for differences in longitude are chiefly to correct one's local time, shown by the Graphic Time Table, to the standard time of our clocks and watches. This correction depends solely on the distance of the observer east or west of his standard time meridian, the latter being an even multiple of 15 degrees: 75°, 90°, 105°, and 120° west longitude in the United States. In the following tabulation, in minutes of time, all places with plus corrections are west of the standard meridian:

Atlanta	+38	Memphis	0
Baltimore	+6	Milwaukee	−8
Birmingham	−13	Minneapolis	+13
Boston	−16	New Orleans	0
Buffalo	+15	New York	−4
Chicago	−10	Oklahoma City	+32
Cincinnati	+38	Philadelphia	+1
Cleveland	+27	Pittsburgh	+20
Denver	0	Rochester	+10
Detroit	+32	Salt Lake City	+28
Helena	+28	San Francisco	+10
Houston	+22	Santa Fe	+4
Indianapolis	−16	Seattle	+10
Kansas City	+18	St. Louis	+1
Los Angeles	−7	Washington	+8


STANDARD TIME
SYMBOLS:
NEW MOON
FIRST QUARTER
FULL MOON
LAST QUARTER
GREATEST ELONGATION
QUADRATURE
OPPOSITION
GREATEST BRILLIANCY (VENUS)
CONJUNCTION
MERCURY
VENUS
EARTH
MARS
JUPITER
SATURN
P. M.
A. M.
MDT.
DECEMBER
NOVEMBER
OCTOBER
SEPTEMBER
AUGUST
JULY
SHORTEST DAY
EARLIEST SUNSET
GREATEST ELONGATION
TOTAL ECLIPSE OF THE MOON
NOV 17-18
MORNING TWILIGHT
EVENING TWILIGHT
NORTH DECLINATION
SOUTH DECLINATION
SETTING
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LUNAR MAP LOCATING TABLE

For each crater in the alphabetical list that accompanies the lunar map are given here the selenographic longitude and latitude, respectively, of the co-ordinate grid intersection that is nearest to the crater. This permits quick location of features that are known by name only.

1	+10	−20	76	0	−70	151	+30	−10	226	−10	−40
2	+10	−10	77	+10	−50	152	+30	+10	227	−10	−30
3	−30	−20	78	+30	−10	153	+40	−40	228	+30	−50
4	+10	0	79	−60	0	154	+10	+10	229	+30	+40
5	0	−10	80	+30	+30	155	−40	+10	230	−10	+50
6	+10	+40	81	−10	−10	156	−20	−30	231	+10	−20
7	0	−30	82	+30	+20	157	−10	+40	232	+20	+20
8	+20	−20	83	−50	−30	158	−30	−70	233	+10	−30
9	0	−20	84	+20	0	159	0	−10	234	+70	−60
10	0	−10	85	+50	+60	160	−70	+20	235	+30	+30
11	+10	−30	86	0	−20	161	−30	0	236	−50	+30
12	+60	0	87	−30	+30	162	−70	−30	237	+50	+20
13	+20	+10	88	0	−50	163	−10	0	238	+10	+50
14	0	+30	89	+20	−10	164	−20	+30	239	0	−10
15	0	+60	90	−30	+30	165	−30	0	240	0	−30
16	−50	+20	91	+10	−10	166	+60	−10	241	−60	+60
17	0	+30	92	−40	−30	167	−10	−20	242	−20	+20
18	+20	+50	93	−70	−20	168	−40	−30	243	+20	−30
19	0	−20	94	−40	0	169	−60	−40	244	−30	−30
20	+20	−50	95	+60	+50	170	−40	−10	245	0	−30
21	+50	+50	96	0	+70	171	−20	+40	246	+50	−30
22	0	+30	97	−10	+10	172	0	−40	247	−60	+10
23	+10	−20	98	−30	−10	173	+10	−50	248	−20	0
24	+20	−50	99	+20	+40	174	+10	−50	249	−70	+50
25	−70	−70	100	−30	+20	175	+30	−30	250	0	0
26	+20	−40	101	+40	−40	176	+10	+30	251	+50	−40
27	−30	−50	102	+10	−40	177	+30	+20	252	−70	0
28	+30	−20	103	+20	−20	178	−70	0	253	+40	+30
29	+60	+30	104	0	−40	179	−20	−50	254	+20	+10
30	+50	+40	105	+60	+10	180	−20	−20	255	+30	−30
31	+20	+20	106	−40	0	181	+20	+10	256	+20	−20
32	−40	−60	107	−20	+60	182	+50	+20	257	+50	−20
33	−30	+50	108	+30	−20	183	+30	−10	258	−10	−40
34	+50	−50	109	−20	−10	184	+40	−10	259	0	−40
35	−50	−10	110	+50	+40	185	−10	−50	260	−30	−60
36	−10	+60	111	+60	−40	186	−40	+40	261	−50	−40
37	−10	−20	112	−10	0	187	+10	+10	262	−40	−50
38	−20	−60	113	−40	−20	188	+30	−70	263	−10	0
39	0	−30	114	−10	−30	189	+30	+20	264	−70	+20
40	+50	−70	115	+70	+40	190	+70	−40	265	−40	+50
41	+40	−20	116	−20	+10	191	+30	0	266	+20	−70
42	0	+60	117	+10	−20	192	−30	+50	267	+60	−30
43	−20	−10	118	+60	+30	193	+10	−40	268	+20	+10
44	+50	−20	119	+10	−30	194	−30	+20	269	−10	+10
45	+10	+10	120	+50	−10	195	+20	+20	270	+60	−30
46	−40	+50	121	+10	0	196	−30	−30	271	+10	−40
47	+70	−70	122	+10	−30	197	−50	−20	272	+50	+60
48	−20	−20	123	−70	−10	198	+60	+40	273	+60	+40
49	+60	+30	124	−40	+30	199	+50	0	274	−70	+20
50	+30	+40	125	−10	−10	200	+40	−40	275	+20	−20
51	+10	+40	126	+40	−10	201	+20	+70	276	+50	+10
52	−30	−30	127	+70	+30	202	−30	+10	277	+10	+40
53	+30	−10	128	−30	−40	203	0	−40	278	0	−20
54	−30	−30	129	+10	−10	204	+50	−20	279	+30	−10
55	−70	+10	130	−50	−10	205	0	−70	280	0	+60
56	−30	−70	131	−40	+50	206	−10	0	281	−10	+30
57	0	+40	132	+60	−30	207	+30	−60	282	+30	0
58	+20	−20	133	−20	−40	208	0	−40	283	0	0
59	−70	+10	134	−20	+40	209	+40	−30	284	−10	−40
60	−50	−20	135	−10	−30	210	+40	−60	285	0	+10
61	+20	−30	136	+10	−50	211	+30	−40	286	+60	−20
62	+50	+40	137	+40	+50	212	+70	−50	287	−60	−30
63	+30	+30	138	−30	−10	213	0	−40	288	−40	−30
64	−20	−30	139	−50	+20	214	−10	−10	289	+30	+20
65	+10	−50	140	0	−10	215	0	0	290	+40	−50
66	−40	−40	141	−40	+60	216	0	−10	291	0	−30
67	−10	−60	142	−20	−30	217	−20	−10	292	−20	−30
68	+60	+30	143	−70	0	218	+50	+20	293	0	−30
69	+50	−10	144	−30	−20	219	+60	−20	294	−20	−40
70	−30	+50	145	0	0	220	−30	+70	295	+20	−30
71	+70	+10	146	−40	+60	221	−60	−50	296	−20	−30
72	0	+20	147	0	0	222	−70	−40	297	0	−60
73	+50	−20	148	−30	+10	223	+60	+10	298	+20	−30
74	−20	+10	149	+70	−30	224	+30	−30	299	−50	−60
75	−70	−20	150	+20	0	225	+50	0	300	−50	−20

Lunar Map

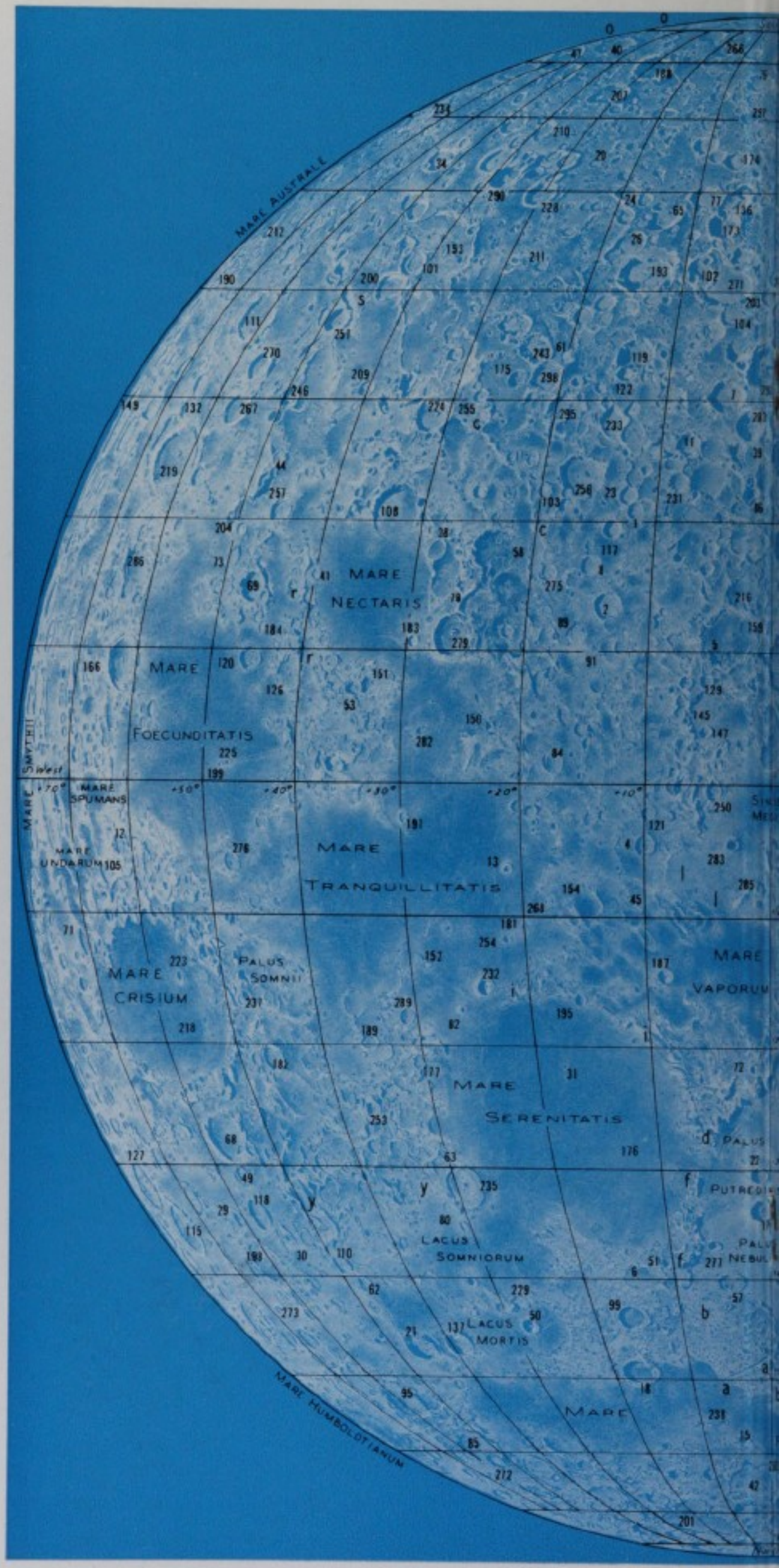
This map of the moon is based on the original drawing by Karel Andel, published in 1926 as Mappa Selenographica. A grid of selenographic co-ordinates has been superimposed. The positions of the numbered craters to the nearest 10 degrees of longitude and latitude are given in the locating table on the reverse side of this page.

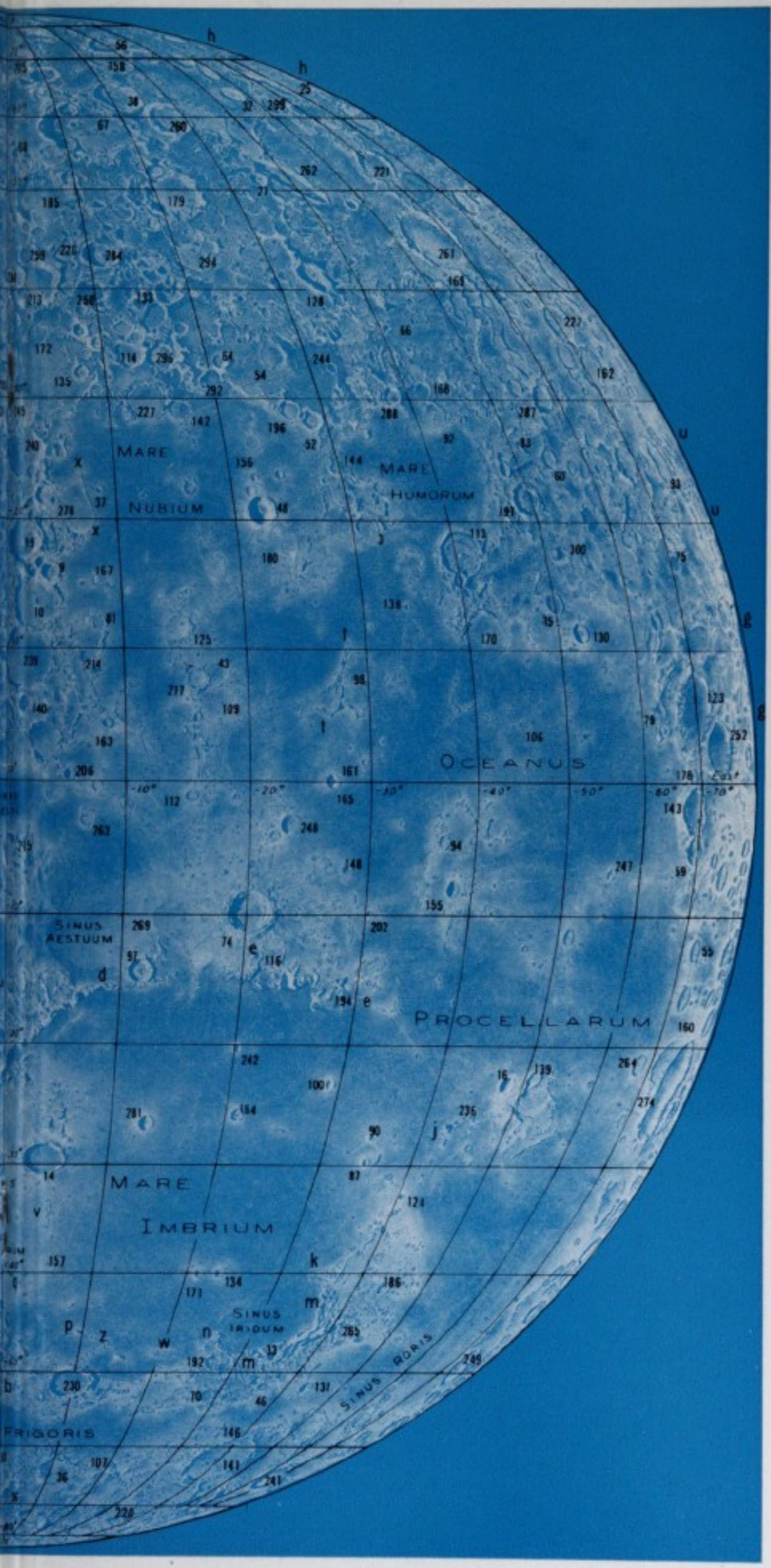
MOUNTAINS AND VALLEYS

a. Alpine Valley
b. Alps Mts.
c. Altai Mts.
d. Apennine Mts.
e. Carpathian Mts.
f. Caucasus Mts.
g. D'Alembert Mts.
h. Doerfel Mts.
i. Haemus Mts.
j. Harbinger Mts.
k. Heraclides Prom.
l. Hyginus Cleft
m. Jura Mts.
n. Laplace Prom.
o. Leibnitz Mts.
p. Pico
q. Piton
r. Pyrenees Mts.
s. Rheita Valley
t. Riphaeus Mts.
u. Rook Mts.
v. Spitzbergen
w. Straight Range
x. Straight Wall
y. Taurus Mts.
z. Teneriffe Mts.

LUNAR CRATERS

1. Abenezra
2. Abulfeda
3. Agatharchides
4. Agrippa
5. Albategnius
6. Alexander
7. Aliacensis
8. Almanon
9. Alpetragius
10. Alphonsus
11. Apianus
12. Apollonius
13. Arago
14. Archimedes
15. Archytas
16. Aristarchus
17. Aristillus
18. Aristoteles
19. Arzachel
20. Asclepi
21. Atlas
22. Autolycus
23. Azophi
24. Baco
25. Bailly
26. Barocius
27. Bayer
28. Beaumont
29. Bernouilli
30. Berzelius
31. Bessel
32. Bettinus
33. Bianchini
34. Biela
35. Billy
36. Birmingham
37. Birt
38. Blancanus
39. Blanchinus
40. Boguslawsky
41. Bohnenberger
42. Bond, W. C.
43. Bonpland
44. Borda
45. Boscovich
46. Bouguer
47. Boussingault
48. Bullialdus
49. Burckhardt
50. Bürg
51. Calippus
52. Campanus
53. Capella
54. Capuanus
55. Cardanus
56. Casatus
57. Cassini
58. Catharina
59. Cavalerius
60. Cavendish
61. Celsius
62. Cepheus
63. Chacornac
64. Cichus
65. Clairaut
66. Clausius
67. Clavius
68. Cleomedes
69. Colombo
70. Condamine
71. Condorcet
72. Conon
73. Cook
74. Copernicus
75. Crüger
76. Curtius
77. Cuvier
78. Cyrillus
79. Damoiseau
80. Daniell
81. Davy
82. Dawes
83. De Gasparis
84. Delambre
85. De la Rue
86. Delaunay
87. Delisle
88. Deluc
89. Descartes
90. Diophantus
91. Dollond
92. Doppelmayer
93. Eichstädt
94. Encke
95. Endymion
96. Epigenes
97. Eratosthenes
98. Euclides
99. Eudoxus
100. Euler
101. Fabricius
102. Faraday
103. Fermat
104. Fernelius
105. Firmicus
106. Flamsteed
107. Fontenelle
108. Fracastorius
109. Fra Mauro
110. Franklin
111. Furnerius
112. Gambart
113. Gassendi
114. Gauricus
115. Gauss
116. Gay-Lussac





117. Geber
118. Geminus
119. Gemma Frisius
120. Goclenius
121. Godin
122. Goodacre
123. Grimaldi
124. Gruithuisen
125. Guericke
126. Gutenberg

127. Hahn
128. Hainzel
129. Halley
130. Hansteen
131. Harpalus
132. Hase
133. Heinsius
134. Helicon
135. Hell
136. Heraclitus
137. Hercules
138. Herigonius
139. Herodotus
140. Herschel
141. Herschel, J.
142. Hesiodus
143. Hevelius
144. Hippalus
145. Hipparchus
146. Horrebow
147. Horrocks
148. Hortensius
149. Humboldt, W.
150. Hypatia

151. Isidorus

152. Jansen
153. Janssen
154. Julius Caesar

155. Kepler
156. Kies
157. Kirch
158. Klaproth
159. Klein
160. Krafft
161. Kunowsky

162. Lagrange
163. Lalande
164. Lambert
165. Landsberg
166. Langrenus
167. Lassell
168. Lee
169. Lehmann
170. Letronne
171. Leverrier
172. Lexell
173. Licetus
174. Lilius
175. Lindenau
176. Linné
177. Littrow
178. Lohrmann
179. Longomontanus
180. Lubiniezky

181. Maclear
182. Macrobius
183. Mädler
184. Magelhaens
185. Maginus
186. Mairan
187. Manilius
188. Manzinus
189. Maraldi
190. Marinus
191. Maskelyne
192. Maupertuis
193. Maurolycus
194. Mayer, Tobias
195. Menelaus
196. Mercator
197. Mersenius
198. Messala
199. Messier
200. Metius
201. Meton
202. Milichius
203. Miller
204. Monge
205. Moretus
206. Mösting
207. Mutus

208. Nasireddin
209. Neander
210. Nearchus
211. Nicolai

212. Oken
213. Orontius

214. Palisa
215. Pallas
216. Parrot
217. Parry
218. Peirce
219. Petavius
220. Philolaus
221. Phocylides
222. Piazzi
223. Picard
224. Piccolomini
225. Pickering, W. H.
226. Pictet
227. Pitatus
228. Pitiscus
229. Plana
230. Plato
231. Playfair
232. Plinius
233. Pontanus
234. Pontécoulant
235. Posidonius
236. Prinz
237. Proclus
238. Protagoras
239. Ptolemaeus
240. Purbach
241. Pythagoras
242. Pytheas

243. Rabbi Levi
244. Ramsden
245. Regiomontanus
246. Reichenbach
247. Reiner
248. Reinhold
249. Repsold
250. Rhaeticus
251. Rheita
252. Riccioli
253. Römer
254. Ross
255. Rothmann

256. Sacrobosco
257. Santbech
258. Sasserides
259. Saussure
260. Scheiner
261. Schickard
262. Schiller
263. Schröter
264. Seleucus
265. Sharp
266. Simpelius
267. Snellius
268. Sosigenes
269. Stadius
270. Stevinus
271. Stöfler
272. Strabo
273. Struve
274. Struve, Otto

275. Tacitus
276. Taruntius
277. Theaetetus
278. Thebit
279. Theophilus
280. Timaeus
281. Timocharis
282. Torricelli
283. Triesnecker
284. Tycho

285. Ukert

286. Vendelinus
287. Vieta
288. Vitello
289. Vitruvius
290. Vlacq

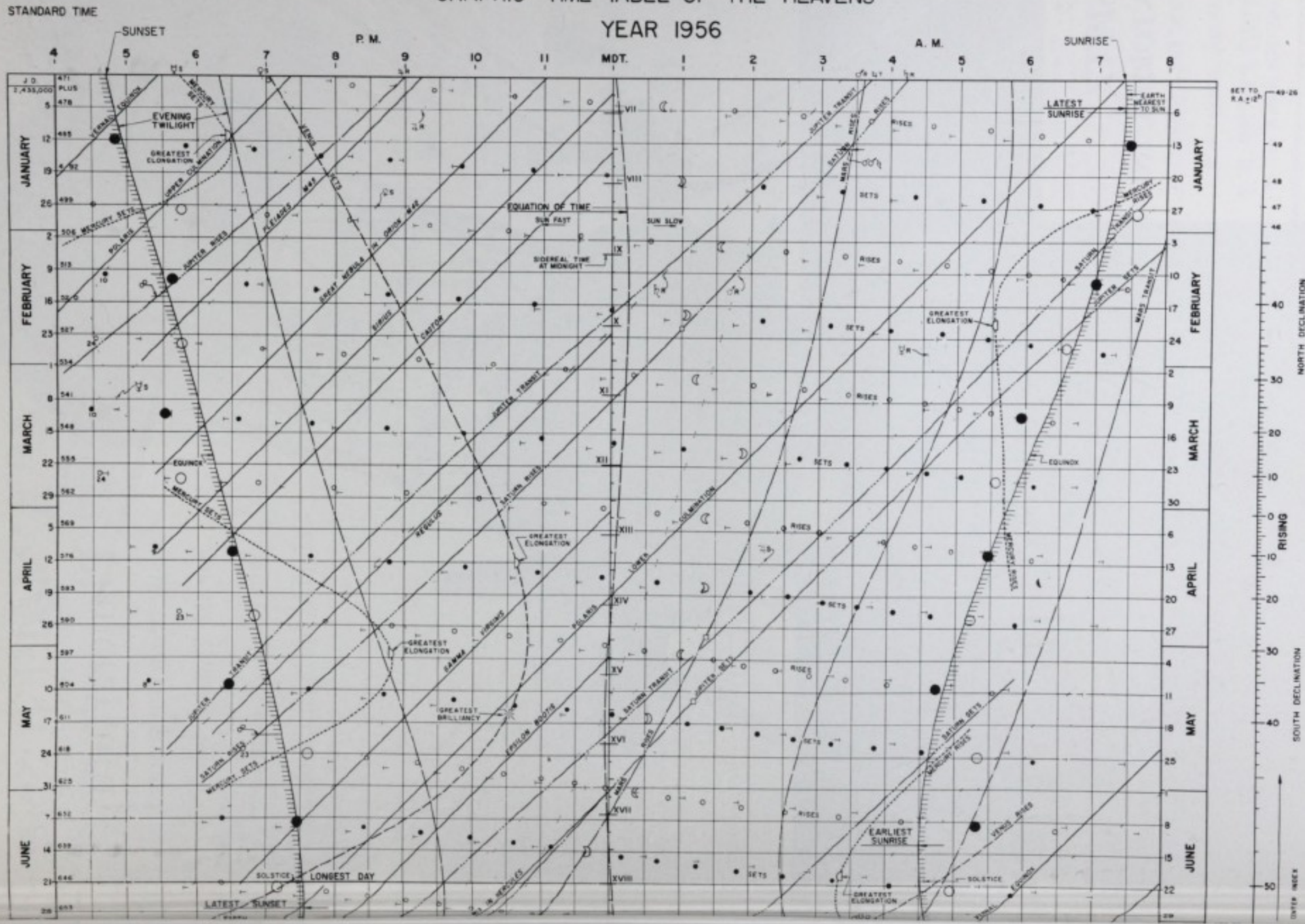
291. Walter
292. Weiss
293. Werner
294. Wilhelm I
295. Wilkins
296. Wurzelbauer

297. Zach
298. Zagut
299. Zuchius
300. Zupus

THE MARYLAND ACADEMY OF SCIENCES

GRAPHIC TIME TABLE OF THE HEAVENS

YEAR 1956



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BOOKS AND THE SKY

WILLIAM HERSCHEL

J. B. Sidgwick. Macmillan Company, New York, 1955. 228 pages. $2.50.

"I have looked farther into space than ever human being did before me," Sir William Herschel said shortly before his death in 1822.

More than 40 years earlier, Herschel had discovered the planet Uranus with a 6-inch reflector made with his own hands. As prince of telescope makers, as prince of observers, he has captured the imagination of succeeding generations. Modern astronomers still mention his studies of galactic structure; observers of double stars, clusters, and nebulae often have occasion to refer to him; planetary and lunar observers, solar physicists, and optical workers sometimes find his name on their lips. Thus, although Herschel's work has been largely superseded, the influence of this pathfinder of the skies has remained through the years.

Mr. Sidgwick has carefully recorded Herschel's long list of studies with commendable clarity. He has, moreover, chronicled the life of William Herschel as musician and astronomer and, crowding much into small compass, has achieved a book which is a rare blend of scientific fact and human interest. He has even found a little space for Caroline Herschel and Sir John Herschel and their discoveries.

From the standpoint of craftsmanship the book is superior, being supplied with a good index, bibliography, and pictures. Perhaps all that one could regret about this sketch of the "father of sidereal astronomy" is that it is so brief.

RALPH S. BATES
State Teachers College
Bridgewater, Mass.

THE GOLDEN BOOK OF ASTRONOMY

Rose Wyler and **Gerald Ames.** Simon and Schuster, New York, 1955. 97 pages. $3.95.

ONE rarely finds a book that carries out its avowed purpose as well as this—namely, to interest intelligent young people in astronomy. The text is very clearly written, the type is excellent, and the numerous illustrations by John Polgreen are outstanding in their artistic beauty.

Approximately 10 by 13 inches in size, each page carries from one to six illustrations, the great majority of them in color. A few are astronomical photographs; most are drawings from photographs, or vividly informative diagrams. Their subject matter ranges from reproduction of part of the Bayeux tapestry, illustrating the appearance of Halley's comet in 1066, to a visualization of space explorers on the moon.

Any person, young or old, who has had no formal course in astronomy or has not read much on the subject, through this book could obtain a better conception of the universe than is had by many a college graduate who has not studied the science. The various subjects are arranged in a logical order so the reader advances step by step. Each chapter is just a few pages long, but is full of information.

Of course, in the wish to shorten all explanations, occasional ambiguities or partial misstatements occur, though in some cases they are cleared up farther on. Among definite errors is the statement on page 15 that solar days are exactly equal in length. For the Palomar telescope (page 35) to bring the moon to within 12 miles would need a power of 20,000, which is impossibly large. Also on page 35, the discussion of temperature measurements is ambiguous, and photometers are confused with heat-measuring devices. On pages 37 and 47 it is said that meteors strike the earth due to its gravitation, whereas meteor orbits are actually only slightly affected by its gravity. There are no spots near the sun's poles (page 56), so they cannot be used to determine the rotation of the polar zones.

But these and some other errors are minor. Indeed, the book can be most heartily recommended, and should make a valuable gift for a child or an attractive addition to one's own library.

C. P. OLIVIER
American Meteor Society

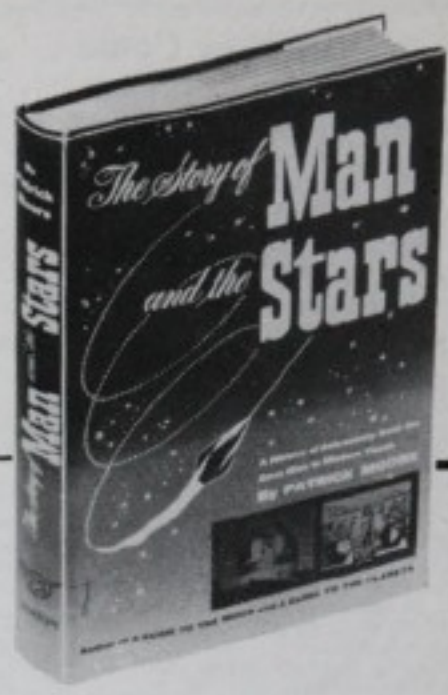
OUR MOON

H. Percy Wilkins. Frederick Muller, Ltd., 110 Fleet St., London E. C. 4, 1954. 180 pages. 12s 6d.

NO OBJECT in the sky makes a better starting point than the moon for the amateur who is just beginning telescopic work. Its broad face welcomes exploration, in even the smallest telescopes. The inexhaustible range of detail in more powerful instruments has led many amateurs into lunar study as a lifelong avocation.

Our Moon has been written mainly for the beginning observer. It has moon charts and descriptions of many interesting formations, and easy-to-read background material. You are told something of the history of selenography, and what today's leading observers have found with large telescopes. Current problems are discussed, such as the actual nature of Linné, the queer apparent changes on the floor of Plato, and the significance of the domes that have recently been discovered in large numbers.

The more advanced observer will want to look at this book, too. Many recent findings, notably by British amateurs, are included, and there are numerous reproductions of detail drawings made by



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207—Sirius (type dA2), 3400-5000 angstroms
208—Deneb (type eA2), 3300-4900 angstroms
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the author as a guest observer with the Meudon Observatory 33-inch refractor. These drawings have much value despite their coarse draftsmanship.

Perhaps the most stimulating chapter is "Mysterious Happenings on the Moon," a collection of more-or-less unexplained observations of night-side flashes, glows, color changes, anomalous shadows, and obscurations of crater interiors. Many of these reports are unconfirmed, and they differ widely in reliability. Generally speaking, they are not a safe basis for theorizing. But it is very worthwhile to list these occurrences, so that more observers will be on the alert to report them carefully in the future.

A striking section of the book deals with the other side of the moon, of which a chart is given. Craters and seas in the marginal zone have been mapped by direct observation, at times when these features are brought into sight by libration. But Dr. Wilkins goes farther. On the plausible assumption that bright rays near the moon's limb diverge from craters on the far side, he has been able to chart nine such centers. He is, however, on much more dangerous ground when he enters on his map hypothetical seas on the moon's far side diametrically opposite the highlands on the visible face of our satellite.

Few living astronomers can equal Dr. Wilkins' familiarity with the moon's surface, and this offers a general guarantee of the reliability of his statements on lunar topography. The emphasis is strongly descriptive, which may give some readers the impression that study of the moon is largely limited to drawing its surface. Perhaps even a popular book should tell more of the results obtained by professionals through the powerful methods of astrophysics, astrometry, and radio astronomy.

There are a few questionable statements in *Our Moon*. It seems now well established, from studies by Dollfus, Kuiper, and Opik, that the greatest possible density of the lunar atmosphere must be far less than the early Lyot value (1/10,000 of the earth's, at most) that the author favors on page 98. Again, on page 140, the assertion that O'Neill's bridge "certainly exists" is a minority opinion, not shared by most of those who have looked for this enigmatic feature. Lastly, is not the "Incognito Mare," described on page 163 as discovered by the author, the same dark marking that Prof. J. Franz called "Mare trans Hahn" as early as 1913?

Our Moon can be recommended to the amateur as an easy introduction to an absorbing subject. It might be described as a simple and inexpensive observing accessory that will double the satisfaction he gets from his telescope.

J. A.

NEW BOOKS RECEIVED

ASTROPHYSICAL QUANTITIES, *C. W. Allen*, 1955, *John de Graff*. 263 pages. $10.00.

This is a collection of tables containing numerical data needed by astronomers, ranging from basic physical units and atomic data through the properties of stellar atmospheres to the size of the universe. Full source references are given. The concise tabulations are mostly intended for the specialist, but should be valuable for teachers and advanced amateurs also.

A POPULAR GUIDE TO THE HEAVENS, *Sir Robert Ball*, 1955, *George Philip and Son*, 30-32 Fleet St., London E. C. 4. 84 pages plus 83 plates. 30s.

Lavishly illustrated with 83 plates, this well-known handbook for amateur astronomers has reappeared in its fifth edition since 1892. The illustrations include solar and planetary photographs, star maps and lunar charts, and photographs of the more conspicuous nebulae and clusters.

METEORS, *T. R. Kaiser*, editor, 1955, *Pergamon Press*. 204 pages. $8.50.

In this volume are collected technical papers on various aspects of meteors, presented at the symposium on meteor physics held in England at the Jodrell Bank Experimental Station in July, 1954. English texts are given for all 39 reports in this book, which forms Vol. II of the special supplements to the *Journal of Atmospheric and Terrestrial Physics*.

The topics include meteor ablation, luminosity, and ionization, spectra, low-energy atomic collision processes, radio echoes, upper atmosphere data from meteors, meteoric influences on the ionosphere, distribution of masses, space density and incident flux, interplanetary dust, meteor orbits by photographic and radio methods, evolution of meteor streams.

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THE STORY OF MAN AND THE STARS
By Patrick Moore $3.95

Handbook of the British Astronomical Association for 1956 .....$1.50
Elger's *Map of the Moon*, 1955 edition..$1.75
Norton's *Star Atlas*, latest edition.....$5.25
Davidson, *Astronomy for Everyman*.....$5.00
Bonner Durchmusterung, revised edition, 1951/53, 64 maps and catalogues...$100.00

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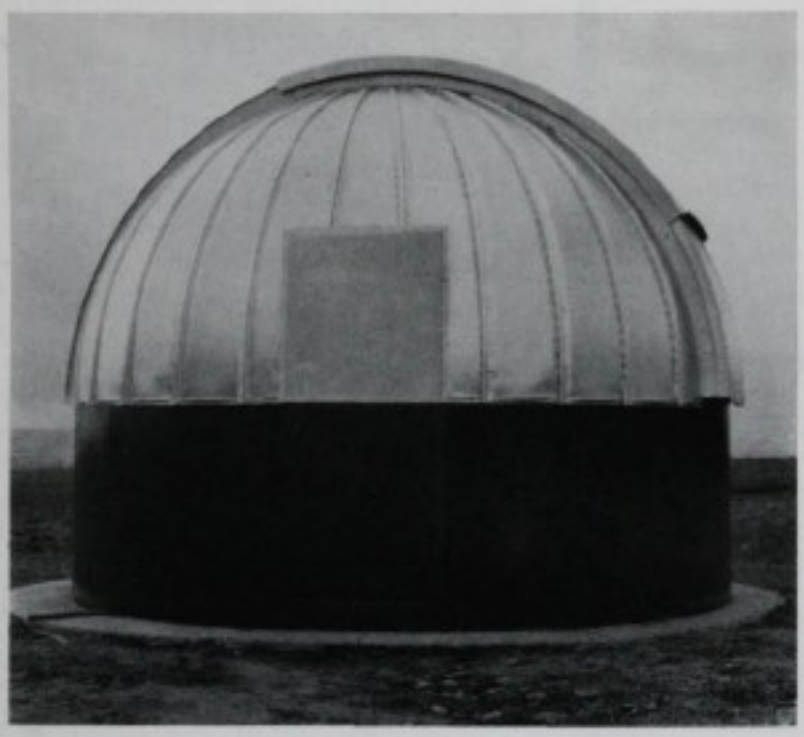

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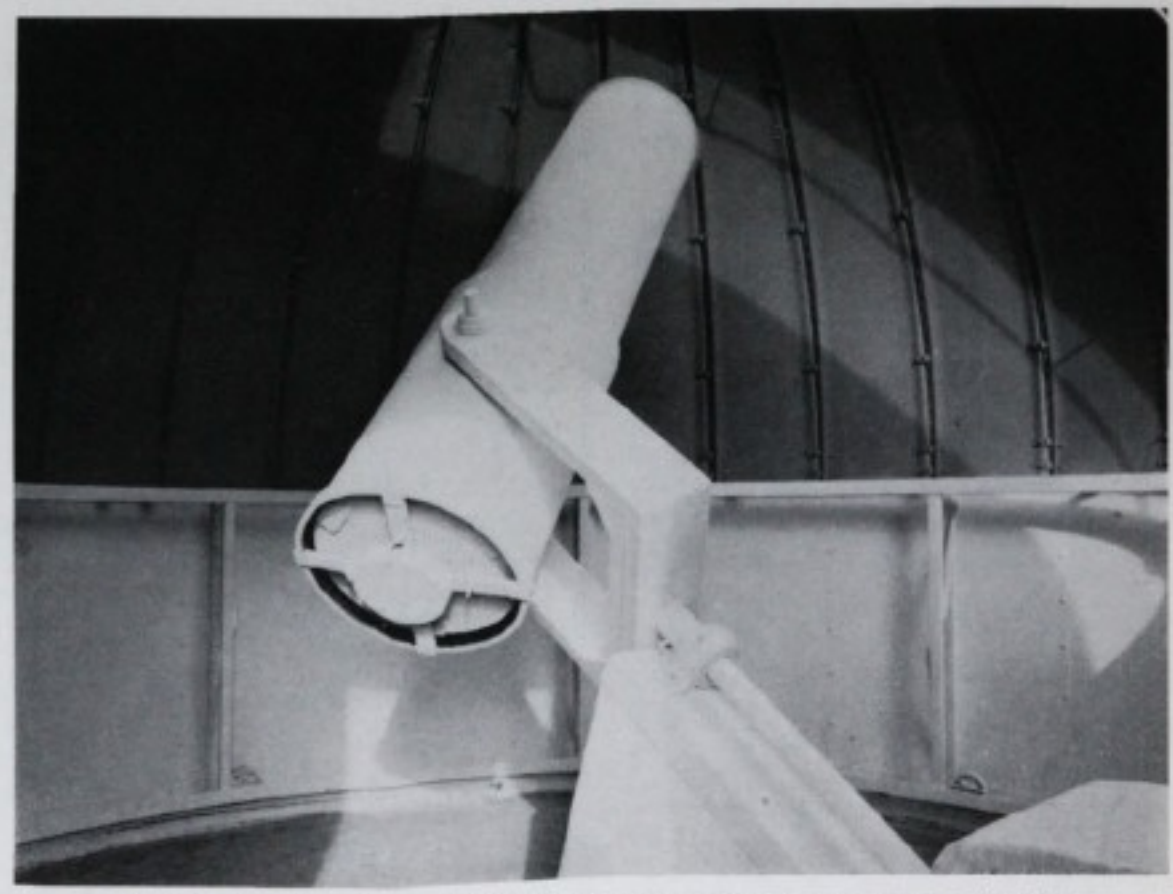

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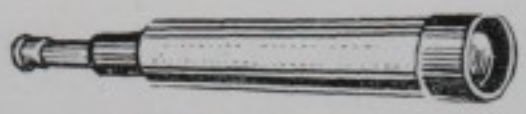

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Notes on Basic Optics—XVII

Q. Achromatic Objectives

Our discussion of aberrations has now proceeded far enough that we can profitably talk about the design of one of the simplest types of optical systems, in frequent use and of particular interest to astronomers—the achromatic objective. By definition, the achromatic objective is constructed of two pieces of glass, and is corrected for chromatic and spherical aberration for an axial point. If the field of view needed is small, off-axis aberrations never become significant, and a lens corrected for the axial image point will be quite satisfactory. This is the case for ordinary astronomical telescopes, with aperture ratios of the order of f/15, and fields of view of a few degrees at most; it is also true for more generally used instruments such as spotting scopes and binoculars.

1. **Design of Achromats.** We saw in our July, 1955, installment that with two types of optical glass it is possible to specify a pair of lenses made from them that will give a desired effective focal length for the combination, and at the same time bring two selected colors of light to the same focal point. It was also noted that one of these two lenses will be positive, the other negative, and that the positive lens will be the one made from the glass of lower refractive index and larger ν-value.

It is possible, therefore, to find a chromatically corrected lens pair from any arbitrary selection of a pair of optical glass types. Actually, useful achromatic objectives will result only when the two selected glasses are crown and flint.

Suppose we have taken a crown and a flint glass, and have determined the ratio of optical powers to achieve chromatic correction for a specified focal length. We can still choose the distribution of power between the two surfaces of the individual elements. This is the process of bending lenses, described in our discussion of spherical aberration in November, 1955. By bending we may correct the lens for spherical aberration without disturbing its chromatic correction.

If we do this for a particular pair of glasses, and plot the spherical aberration resulting from a succession of bendings, we will have a curve somewhat like that shown in Fig. 54. The curve is a parabola, whose position depends upon which kinds of glass were chosen. Not every pair selection will lead to useful lenses, because some pairs will give parabolas that do not cut the zero spherical aberration axis, and correction for spherical aberration will not be possible by bending.

For most crown and flint pairs, however, there will obviously be two corrected solutions. Actually, there are four, because two parabolas can be drawn—one representing the case of the crown element toward the object, and one for a "flint-in-front" type. The choice among these four possible solutions usually rests

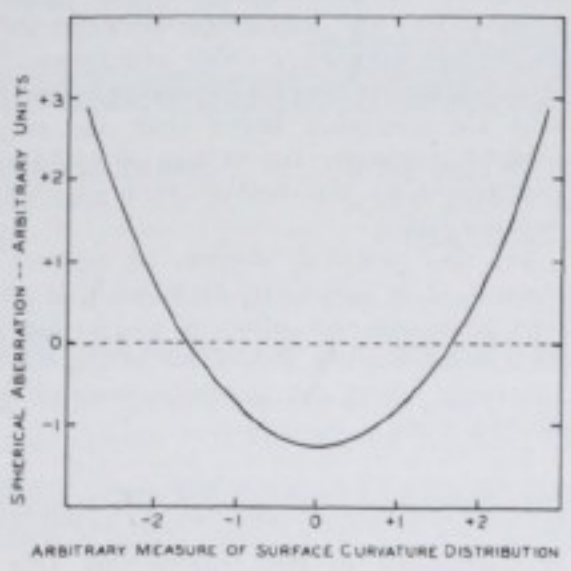

Fig. 54. Spherical aberration for various bendings of lenses in contact.

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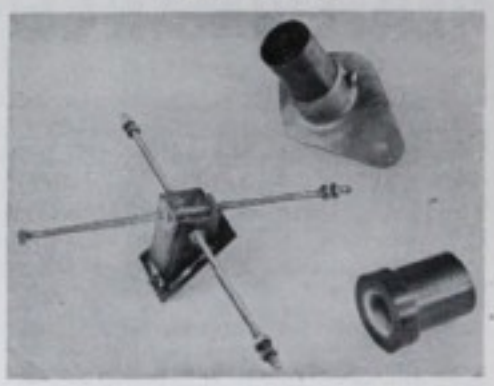

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upon the degree of correction obtained for off-axis aberrations; or, if maximum performance is not essential, the choice is the one that is easiest and cheapest to manufacture.

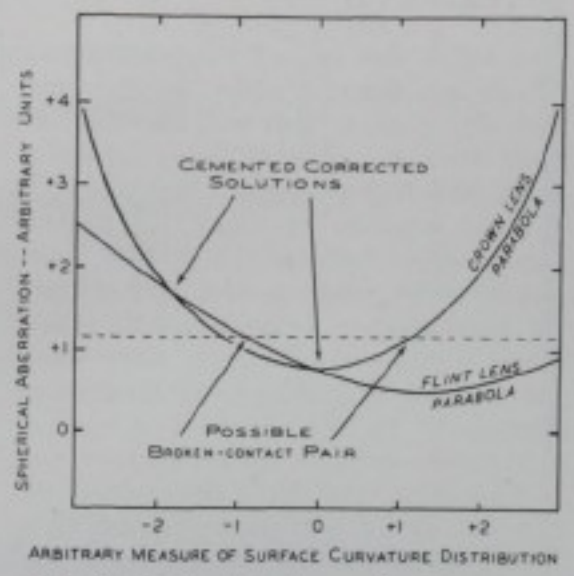

Fig. 55. Spherical aberration for separate elements of an achromatic lens.

2. **Broken-contact Solutions.** This discussion has assumed that the lens pair is to be cemented. For reasons of economy and ease of assembly, a cemented achromat is greatly to be preferred over one where the two lenses have an air space between them, and in which the two curvatures adjacent to the air space are different. In large astronomical telescopes, however, it is important to have the highest degree of correction possible; for this, a "broken-contact" design is generally used.

To illustrate this, we may draw two parabolas, as in Fig. 55. One parabola shows the spherical aberration of the crown element plotted against various bendings; the second parabola is for the spherical aberration (with sign reversed) of the flint element. In general, a horizontal straight line cuts the two parabolas at two points each. These points represent spherical aberration contributions, opposite in sign, and therefore possible lens combinations corrected for spherical aberration. There are an infinite number of possible solutions, one for each horizontal line; however, few of these possibilities are useful in leading to acceptable values for other aberrations. It is frequently possible to find solutions that are somewhat better than the cemented solutions; the latter, of course, correspond to the intersections of the two parabolas.

In the practical design of optical systems, it is frequently required that a lens have non-zero spherical aberration; such solutions can be found in Fig. 55 at points where the parabolas have the desired vertical separation.

Fig. 55 is based on the assumption of zero separation between the two lenses; in practical designs, the aberrations can be controlled in part by varying this separation. Graphical ray tracing presupposes zero axial thickness for all components, including the air space; in actual ray-trace calculations, the finite thicknesses of the optical spaces require slight adjustments of the curves to achieve complete correction.

3. **Residual Aberrations.** The definitions of both chromatic and spherical aberration concern the distance between the intersections of two given rays with the optical axis. For chromatic aberration, these rays are paraxial, and of two specified wave lengths; for spherical aberration, one ray is paraxial and the other is at some selected height in the aperture.

The important point is that the aberrations, if dealt with by the procedures we have discussed, are corrected only for selected pairs of rays. We must not assume that the correction holds for all other ray pairs. Consider a cemented achromat, say, for which red and green light through some particular zone of the aperture come to a common intersection point, and for which a ray of some one color through the edge of the aperture comes to the same intersection point with a paraxial ray of this color. Then we must expect that rays of different colors, passing through different aperture zones, will exhibit **residual** amounts of aberration, both spherical and chromatic.

Chromatic residuals show up as the secondary spectrum, described in the

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September, 1955, installment. There is a spread along the optical axis of all colors other than the pair for which correction is attained.

Residual spherical aberration occurs for all zones except the one for which the spherical correction was achieved. Some mention was made of it in November. In telescopes with aperture ratios of f/6 or greater, it seldom attains unacceptable amounts. Usually in ordinary achromatic telescopes the best course is to correct fully the extreme marginal ray.

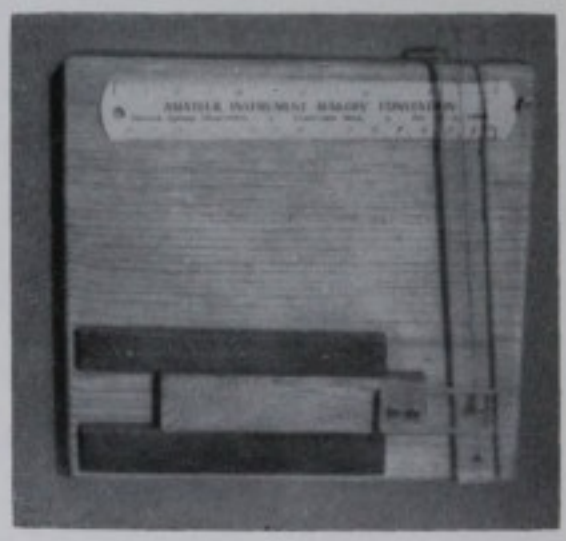
One other important aberration should be mentioned at this point, the variation of chromatic aberration with the height of the rays in the aperture, or chromatic variation of spherical aberration. It is usually called **spherochromatism.** Little can be done about it in the simple doublet objective, except to select glass types that minimize it; in some kinds of optical systems, however, it is quite important.

(To be continued)

A SCALE FOR MEASURING PARABOLOIDAL CORRECTION

ZONAL measurements during the later stages of making a mirror can be carried on accurately and confidently by the simple apparatus described here. In the diagram, K-K′ represents the maximum amount of travel required by the knife-edge of the testing apparatus. It is customary to place an accurate scale here, sometimes expensively etched to procure the highest degree of precision.

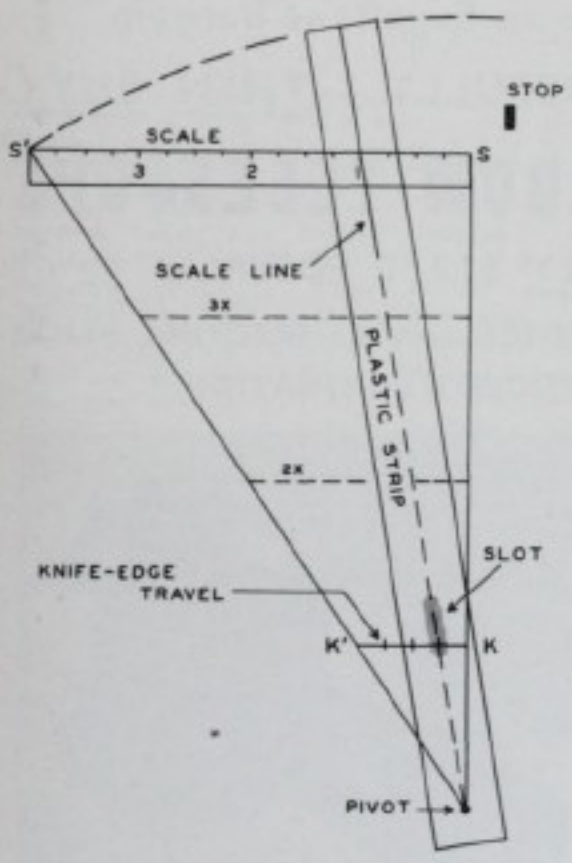
But the apparatus shown in the picture obviates this expensive scale. Instead, along S-S′ is placed a conventional ruler or straightedge marked at appropriate intervals. If we want to measure any distance along K-K′, then S-S′ provides



A simple model made by Robert E. Cox illustrates the method proposed by Kelvin Masson to obtain more accurate readings of knife-edge settings. The amplification in this model is over six times, from 1/100 to 1/16 inch. The setting in the picture corresponds to the paraboloidal correction on a 6-inch mirror of 48 inches focal length.

an easier scale to measure, for its intervals are larger than those of K-K′ by any desired factor, in this case four.

The critical factors in this arrangement are: The knife-edge should move against its cleat; the distances should be read off as accurately as possible; and the straight-edge should be tested against a pane of glass. It is convenient to have S-S′ an exact multiple of K-K′; five or six times is about the practical limit.



This diagram of Mr. Masson's plan has been labeled to match the parts of the model in the picture opposite, but the scale enlargement here is exactly four times. The setting represents the correction on an 8-inch rich-field mirror of f/4. In practice, the scale K-K′ is not needed. The dashed lines show the positions of scales for reading amplifications of two or three times.

In Mr. Cox's model, there are two pivot points, one engaging a slot cut in the movable arm with its long axis along the scale line of the arm. The arm is made of transparent plastic with its scale line scribed along the bottom. The arm extends well beyond S, in order to reach the other end of the scale at S′. The knife-edge must be placed on the block so the viewing edge is exactly over the line K-K′.

The unit is used as follows: After setting the movable arm to zero, the knife-edge is carefully set for the inside zone of the mirror to be tested. Then the knife-edge block is slowly drawn along the line K-K′ until the outside zone is reached. The pin in the slot of the arm draws it along, swinging the pointer arm over the scale to indicate the measurement.

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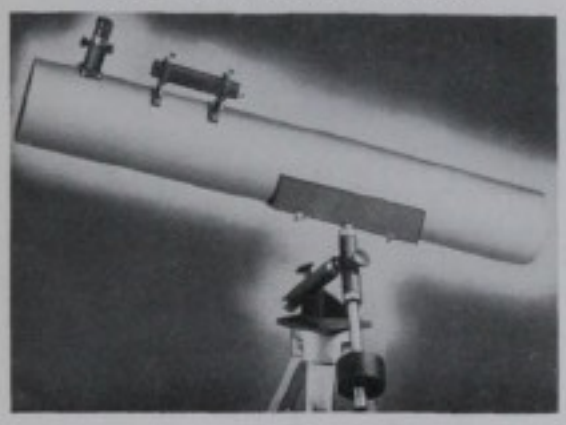

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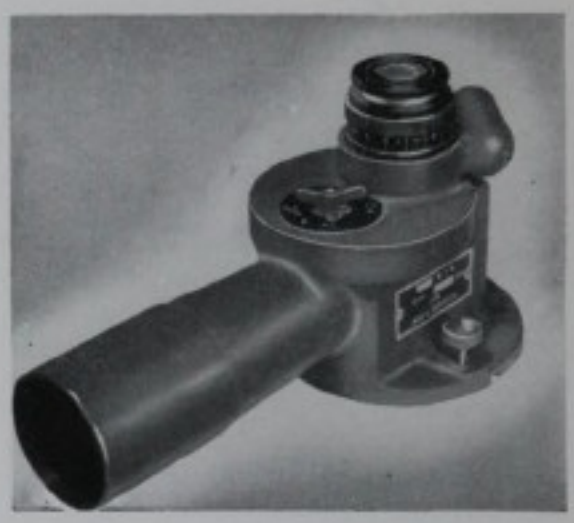

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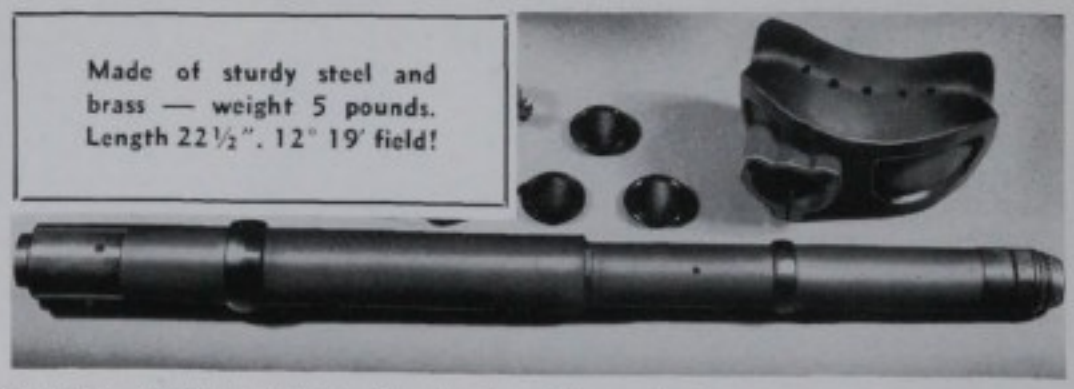

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By removing 3 screws, you can separate scope into 2 pieces, one of which makes an excellent 6-power finder for an astronomical telescope on which reticle can be illuminated for night use. To give you some idea of the intrinsic value you are getting here — as surplus, the lenses alone would cost double the price we are asking for the entire instrument. Bear in mind, too, that the eyepiece by itself can be used for an astronomical telescope.

Stock #80,055-Y Completely boxed with protective absorbent, exactly as received from Army (new or near new) ..... $7.50 ppd.

Stock #80,051-Y Telescope only (used—good condition) ..... $4.00 ppd.

THE MOUNTING RINGS FROM OUR STANDARD 7-POWER FINDER CAN BE USED ON THE ABOVE M-70 TELESCOPE

Stock #50,075-Y Ring mounts per pair ..... $4.95 ppd.

EDMUND SCIENTIFIC CORP.

ACHROMATIC ASTRONOMICAL TELESCOPE OBJECTIVES

Real Quality at Bargain Prices

Make Wonderful Refractors

For three years we checked U.S., German, and Japanese manufacturers looking for one who could produce really good telescope objectives at a low price. A few times we ordered samples only to be disappointed in quality or final price. Finally, we found a Japanese optical engineer who designed some excellent astronomical objectives. We place orders with him. He then has these made, checking each one for quality. Thus, we are able to offer objectives we believe to be as good as those selling for two or three times our price.

Our 3" and 4" diameter objectives are air-spaced achromats, as air-spacing gives the lens designer four surfaces with which to correct aberrations, instead of only three as in a cemented achromat. The results are a beautiful, color-free image, sharp, clear, with very flat field, no bad zones, and full correction against coma.

Stock No.	Diam.	F.L.	Price	Comments
30,166-Y	3"	45"	$28.00	Not coated
30,190-Y	3"	45"	32.00	Coated
50,106-Y	4"	60"	60.00	Not coated
50,107-Y	4"	60"	69.00	Coated on four surfaces

Metal cells are available for the objectives above.
Stock #70,063-Y.....$11.95 for 4" objective
Stock #70,064-Y.....$10.95 for 3" objective

LOW COST, LONG F.L. ACHROMAT
Stock #30,187-Y 50" F.L., 2" d'am., coated . . . $12.50 ppd.

Rack & Pinion Eyepiece Mounts

For Reflectors

For Refractors

Now you can improve performance in a most important part of your telescope — the eyepiece holder. Smooth, trouble-free focusing will help you to get professional performance. Look at all these fine features: Real rack-and-pinion focusing with variable tension adjustment; tube accommodates standard 1¼" eyepieces and accessory equipment; lightweight aluminum body casting; focusing tube and rack of chrome-plated brass; body finished in black wrinkle paint. No. 50,077-Y is for reflecting telescopes, has focus travel of over 2", and is made to fit any diameter or type tubing by attaching through small holes in the base. Nos. 50,103-Y and 50,108-Y are for refractors and have focus travel of over 4". Will fit our 2⅜" I.D. and our 3⅜" I.D. aluminum tubes respectively.

Stock #50,077-Y (less diagonal holder) $9.95 ppd.
Stock #60,035-Y (diagonal holder only) 1.00 ppd.
Stock #50,103-Y (for 2⅜" I.D. tubing) 12.95 ppd.
Stock #50,108-Y (for 3⅜" I.D. tubing) 13.95 ppd.

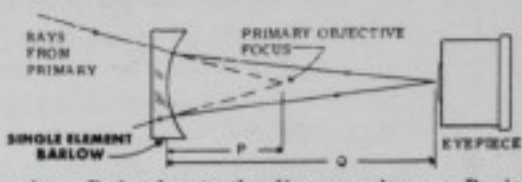
HUYGENS EYEPIECES

Here are some really terrific values in eyepieces! The three eyepieces listed below are manufactured by one of the world's best producers of optical components. We have searched the world's markets, including Germany and France, to find a real quality eyepiece. The image clarity, the workmanship evidenced in the metal parts, will prove the skill and experience of Goto Optical Company, Tokyo. Guaranteed terrific buys!

HUYGENS TYPE — STANDARD 1¼" DIAM.
6 mm. (¼") Focal Length
Stock #30,063-Y ..... $8.50 ppd.
12.5 mm. (½") Focal Length
Stock #30,064-Y ..... $8.00 ppd.

COMBINATION EYEPIECE—10 mm. and 20 mm.
Stock #30,065-Y ..... $9.00 ppd.

DOUBLE AND TRIPLE YOUR TELESCOPE'S POWER with a BARLOW LENS



WHAT IS A BARLOW? A Barlow lens is a negative lens used to increase the power of a telescope without resorting to short focal length eyepieces, and without the need for long, cumbersome telescope tubes. Referring to the diagram above, a Barlow is placed the distance P inside the primary focus of the mirror or objective. The Barlow diverges the beam to a distance Q. This focus is observed with the eyepiece in the usual manner. Thus, a Barlow may be mounted in the same tube that holds the eyepiece, making it very easy to achieve the extra power.
The new power of the telescope is not, as you might suppose, solely due to the extra focal length given the objective by the difference between P and Q. It is defined as the original power of the telescope times the quotient of P divided into Q!
ACHROMAT OR SIMPLE BARLOW? An achromatic Barlow lens will give best results, but our low-priced single-element lens will give you 90% of the performance of the achromat. In fact, on and around the axis, the image will be just as good, with slight additional color at the edges of the field. SINGLE ELEMENT BARLOW — FOCAL LENGTH 1-5/16". Our short focal length means that you do not have an unwieldy long tube at the eyepiece.

Stock #30,175-Y. Unmounted. O.D. 1-3/16". Coated. Fits in tubing listed below. $3.00 ppd.

Stock #30,140-Y. Mounted Achromatic Barlow Lens ..... $15.00 ppd.
30-day Money Back Guarantee as with all our Merchandise!

BRASS TUBING

2 pieces, 3" long, slide fitting. Blackened brass. I.D. 1-3/16", O.D. 1-5/16". To fit single-element Barlow above.
Stock #40,165-Y ..... $1.25 ppd.

7X — FINDER TELESCOPE — ACHROMATIC

Stock #50,080-Y Finder alone, less ring mounts $9.95
Stock #50,075-Y Ring mounts per pr., $4.95

ASTRONOMICAL TELESCOPE TUBING

Stock No.	I.D.	O.D.	Lgth	Description	Price
80,038-Y	4⅞"	5⅛"	46"	Spiral-wound paper	$2.50
85,008-Y	7"	7½"	60"	Spiral-wound paper	4.00
85,011-Y	2⅜"	3"	48"	Aluminum	6.00
85,012-Y	3⅜"	4"	60"	Aluminum	8.75
85,013-Y	4⅜"	5"	48"	Aluminum	9.00
85,014-Y	6⅜"	7"	60"	Aluminum	15.00

All tubing is shipped f.o.b. Barrington, N. J.

MOUNTED ERFLE EYEPIECE

68° FIELD OF VIEW

Consists of 3 coated achromats in metal mount with spiral focusing. F.L. 1¼". Diam. 54 mm., length 54 mm. War surplus. Govt. cost about $84.00. This is the type war-surplus bargain that will be talked about in years to come. Buy while you can.

Stock #5160-Y, $12.50 ppd.

ADAPTER

Provides 1¼" diameter mount to fit standard eyepiece holders.
Stock #30,171-Y ..... $3.95 ppd.
1¼" diam.

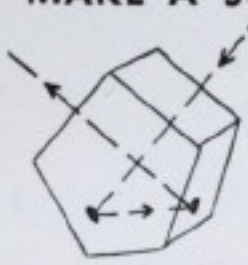
WAR SURPLUS

TELESCOPE EYEPIECE

Mounted Kellner Eyepiece, Type 3. 2 achromats, F.L. 28 mm., eye relief 22 mm. An extension added, O.D. 1¼", standard for all types of telescopes. Govt. cost $26.50.

Stock #5223-Y, $5.95 ppd.

MAKE A SUN DIAGONAL



Because it is unsilvered, this PENTA PRISM transmits only .0016 of the light it receives, making it an excellent sun viewing diagonal, if used with proper precautions. Entrance and exit faces 1" and 1" approximately.

Stock #3262-Y $3.75 ppd.

"MAKE-YOUR-OWN" 4¼" MIRROR KIT

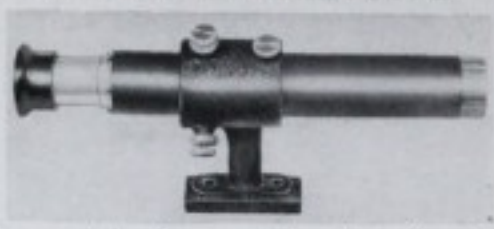
The same fine mirror as used in our Palomar, Jr., polished and aluminized, lenses for eyepieces and diagonal. No metal parts.
Stock #50,074-Y ..... $16.25 ppd.

LATEST MODEL

SPITZ Jr. PLANETARIUM

Designed by Armand Spitz. Projects nearly 400 stars, more than 70 constellations in their correct relationships. Use it in any darkened room of the house, project it on walls and ceiling. No batteries, works on ordinary household current. Two simple adjustments that show you the sky as it appears from any point in the Northern Hemisphere . . . for any time of night . . . for any month of the year! Rheostat brightness control. A 32-page book included free of extra cost. Contains valuable information about the stars, provides easy identification of the constellations. Also FREE — illuminated pointer.
About 14" high on a 7" x 7" base.
Stock #70,040-Y ..... $14.95 ppd.
Stock #70,059-Y Sky Zoo Projector ..... $3.98 ppd.
Stock #70,060-Y Southern Hemisphere Projector ..... $3.98 ppd.

5X FINDER TELESCOPE



Has crosshairs for exact locating. You focus by sliding objective mount in and out. Base fits any diameter tube — an important advantage. Has 3 centering screws for aligning with main telescope. 20-mm. diam. objective. Weighs less than ½ pound.
Stock #50,121-Y ..... $8.00 ppd.

MISCELLANEOUS ITEMS

KELLNER EYEPIECE — 2" focal length (1¼" O.D.). Mount of black anodized aluminum.
Stock # 30,189-Y ..... $6.00 ppd.

60° SPECTROMETER PRISM — Polished surfaces 18 mm. x 30 mm. — flat to ½ wave length.
Stock #30,143-Y ..... $8.25 ppd.

BE SURE TO GET FREE CATALOG "Y"
Fantastic variety — never before have so many lenses, prisms, optical instruments, and components been offered from one source. Positively the greatest assembly of bargains in all America imported! War Surplus! Hundreds of other hard-to-get optical items. Write for Free Catalog "Y."

ORDER BY STOCK NUMBER . . . SEND CHECK OR MONEY ORDER . . . SATISFACTION GUARANTEED!

BARRINGTON • NEW JERSEY

Your Personal Stairway to the Stars

THE BALscope Sr. TELESCOPE

The wisdom of dealing with traditional craftsmen is easily proved when you first use the BALscope, Sr. 60 mm telescope.

You can carry it anywhere . . . it's compact. Even the beginning amateur can focus with perfect accuracy, because of its unique prism-focusing system—the first *real* advance in telescope design in many years.

Use it on any pan-head camera tripod with the Bausch & Lomb tripod adapter and vary the power to suit the subject. Four easily interchangeable eyepieces ranging from 15× to 60× offer excellent results from Star Clouds to Double Stars.

Of course, it's also the finest terrestrial telescope available.

BALscope, Sr. with 15×, 20×, 30× or 60× eyepiece $95.00

Extra Eyepieces, each 25.00

Tripod adapter (permits use of BALscope, Sr. with any pan-head camera tripod) 6.85

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BAUSCH & LOMB

SINCE B&L 1853

OBSERVER'S PAGE

Universal time is used unless otherwise noted.

Astrophotography for the Amateur — I

MANY amateur astronomers want to photograph what they observe, and perhaps use their pictures to make slides to show to their friends. The writer has developed methods for obtaining negatives suitable either for standard-sized lantern slides or those used in 2-by-2 projectors.

The various objects in the sky may be divided into four groups, each requiring a different plate scale. The first consists of large areas of the sky, including such extensive constellations as Ursa Major and Orion. The next includes smaller star groups, such as Cassiopeia, Lyra, and the Hyades. The third is comprised of most individual open star clusters, nebulae, and nearby galaxies—the Double Cluster in Perseus, the Orion nebula, and so on. Finally, requiring the largest plate scale of all, are the planets, portions of the moon, the Ring nebula in Lyra, and most galaxies.

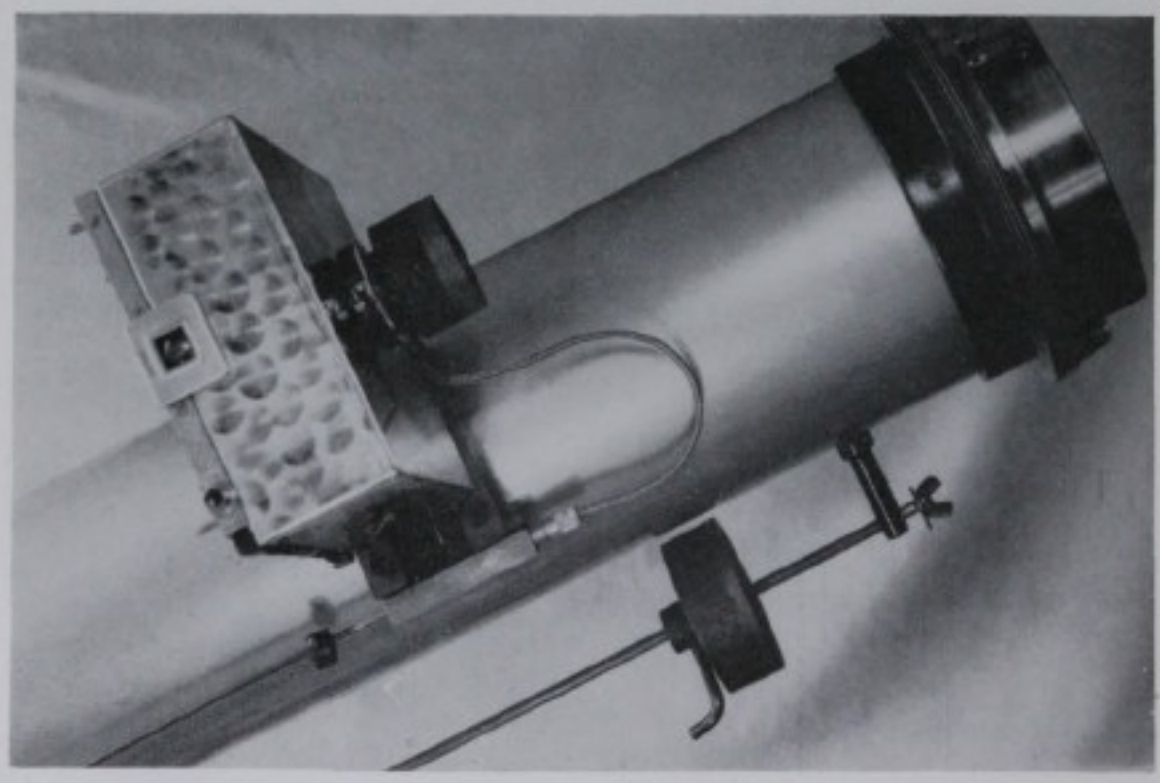
My experience is based on photography with my 5½-inch refractor, which has an f/15 objective. It has a good sidereal drive, which is a prime requisite for successful photography. For this work a good 4-inch to 6-inch telescope is needed, and at least one of the cameras I shall describe.

For the first group of sky objects, an f/3.5 lens of 3-inch focus is about right to obtain negatives that will make 2-by-2 slides directly. The picture shows a simple camera that is attached to a dovetailed bracket near the front end of the telescope tube. The dewcap is removed to avoid obstructing the field. The telescope is used for guiding, and since the exposures with fast lenses such as a Zeiss Tessar are short, 10 to 15 minutes, the strain of guiding is bearable.

This is the attachment for taking pictures in the third group of sky objects.

For the second group, the same arrangement is used, but my camera has an f/4.5 lens of 6-inch focal length.

To open and close the camera shutter, I use a short cable release, the button of which is inserted in a barrel fastened to the dovetail bracket on the telescope and held in by a knurled and threaded bushing around the cable. Into the other end of the barrel there is fixed a 1/8″



The camera of 3-inch focus is here not pushed down to its final position, to show the dovetail bracket on the telescope tube as well as the cable-release and push-rod combination for remote shutter control.

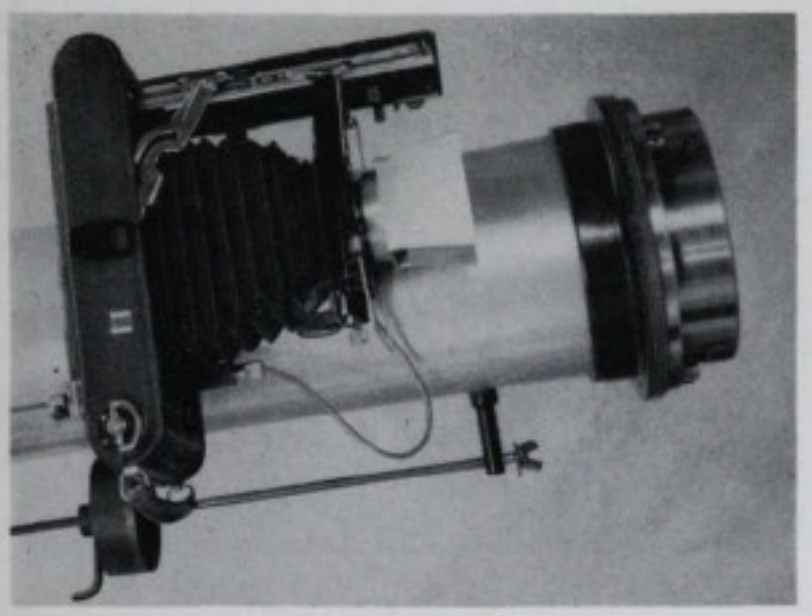
brass rod that extends to the eye end of the telescope through holes in the saddle pieces. Near the barrel, the rod has an adjustable split stop-ring that determines how far the rod can be pushed—this protects the cable release from strain. The shutter is set at bulb; pushing the rod opens the shutter; pulling the rod closes it—no mistake possible.

The field of good definition for a long-focus refractor permits excellent focal-plane photographs to be taken of the third group of objects, by means of a special attachment which is exchanged for the observing tailpiece of my instrument. It is made up of a triple-leaved shutter as shown in the picture, pressure-vacuum operated for 1/30 second and time exposures. The field of view is 3" in diameter on 3¼-by-4¼ cut film.

Since at f/15 the exposures are relatively long, guiding is important. Therefore, the finder is converted to a longer focus by means of a Barlow lens.

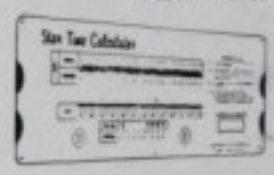
Using this prime-focus camera for objects in the fourth group is very difficult. Mars, for instance, has an image 1/5 millimeter in diameter, and Saturn's ring is only half a millimeter. Therefore, recourse had to be taken to projection through an eyepiece. I shall describe the camera developed for this purpose next month.

HANS PFLEUMER
596 First Ave.
New Brunswick, N. J.



For photographing objects of the second group, this 6-inch camera is used. Its back takes 3¼-by-4¼-inch cut film. The same bracket and shutter control mechanism are used as with the 3-inch camera.

NEW - NEW - NEW



Star Time Calculator

Handy slide-rule type calculator enables you to obtain sidereal time in a matter of seconds. Good for any longitude, day of the year, standard time zone, and time of day. Accuracy to within several minutes is more than adequate for setting-circle use. Printed in two colors on sturdy 10" x 3½" cardboard. Reverse side lists 39 major star clusters and nebulae.

A useful tool for all who are interested in astronomy. Satisfaction guaranteed.

$1.00 postpaid

STAR TIME CALCULATOR
RR 2, Box 375, Buchanan, Michigan

Precision Orrery

18" As Illustrated $70.00

In colors. Lucite and brass gears. Accuracy 1/1000 in 1 part. Gold stars in zodiacal constellations. Synchro-driven.

A. S. DeVANY
1580 S. Ynez Ave., Monterey Park, Calif.

ASTROLA
REFLECTING TELESCOPES
AMERICAN MADE

NEW MODEL "A", 6-inch **$295.00**
NEW MODEL "B", 8-inch **$375.00**

The above are supplied with fiberglass tube, three of the finest orthoscopic oculars giving powers of 72x, 180x, and 315x on MODEL "A", and 84x, 210x, and 360x on MODEL "B".

Clock drive, setting circles, and rotating tube available for above when desired:

Clock drive **$70.00** Circles **$60.00** Rotating Tube **$70.00**

We are now offering a new Richest Field ASTROLA, unmounted, 24" focal length, 6-inch mirror, with 28-mm. ocular. The tube is 26 inches long and the telescope may be cradled in the arms. **$125.00**

Observations of Mars will soon be in order. If you are not satisfied with the performance of your mirror, we will refigure it at a reasonable price.

F/8 parabolic mirrors and elliptical pyrex diagonals, aluminized and quartz coated, corrected to ⅛ wave or better:

6"	$ 60.00
8"	$ 92.50
10"	$160.00

All prices F.O.B. our plant, Long Beach, Calif., and subject to change without notice.

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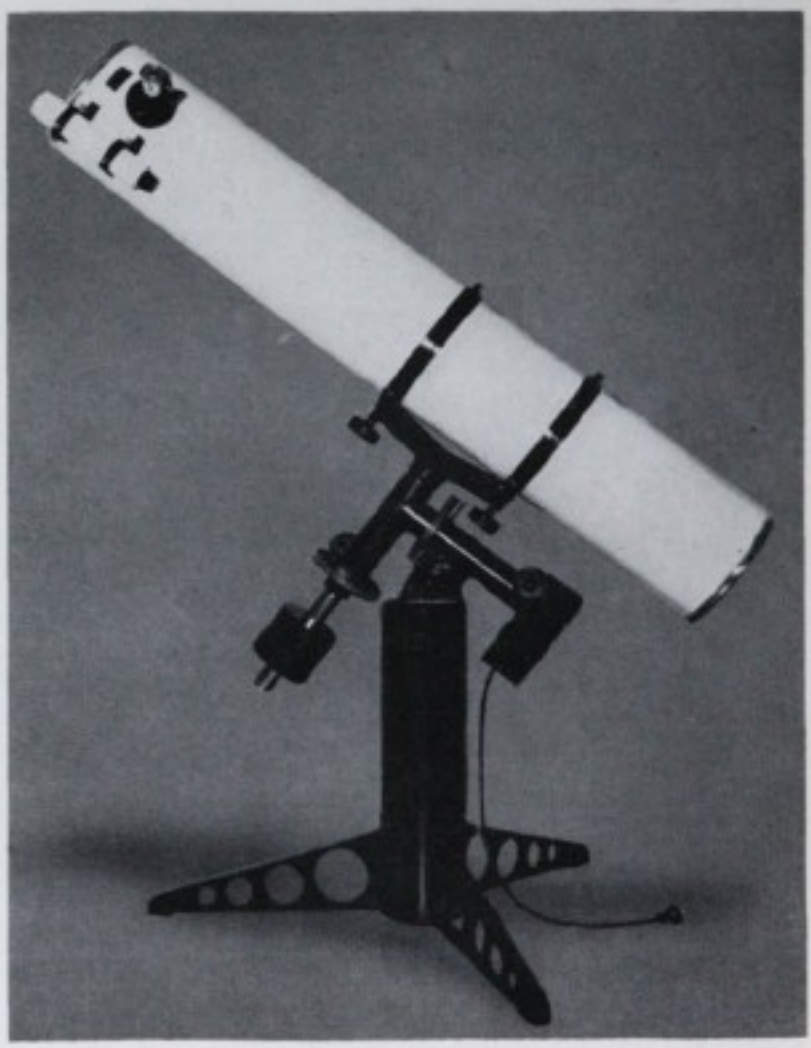
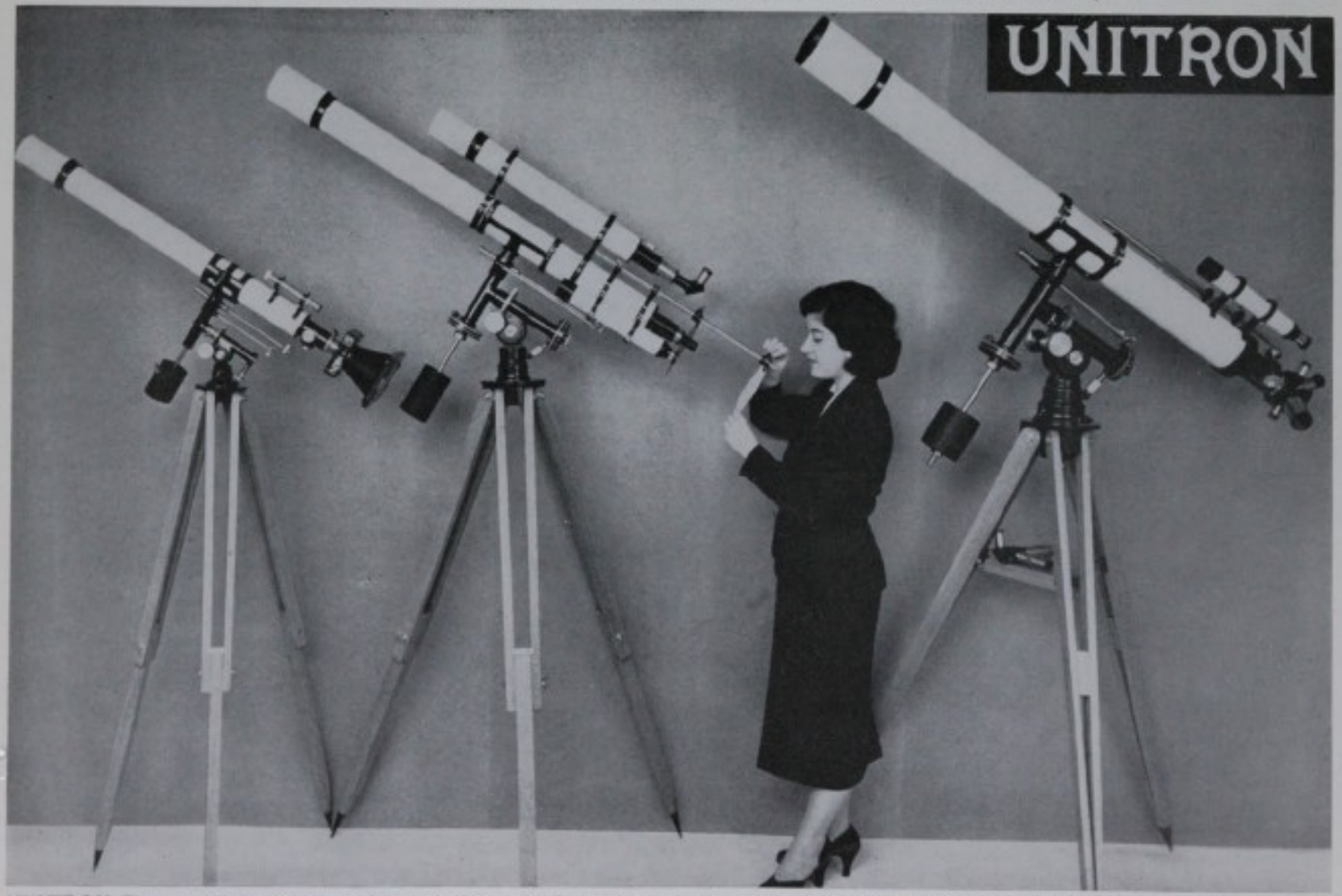
4137 E. Anaheim, Long Beach 4, Calif.



The above is the new De Luxe Model "B", 8-inch, with electric clock drive, setting circles, and rotating tube **$575.00**

UNITRON Altazimuth Refractors: left to right, 1.6″ (with star diagonal), 2.4″ (with erecting prism system), 3″ (with DUETRON double eyepiece), and 4″ (with astro-camera and UNIHEX on the shelf).



UNITRON Equatorial Refractors: left to right, 2.4″ (with astro-camera), 3″ Photo-Equatorial (with sun screen), and 4″.

UNITRON has a *New Catalog* and *Observers Guide* for you

MANY Models To Choose From!

Pictured on the left are seven of the eleven models of UNITRONS currently available. The UNITRON line of telescopes and accessories is the completest ever offered. More UNITRONS are sold than any other equivalent telescopes—there must be a reason!

1.6" ALTAZIMUTH ($19 Down) **$75**
with eyepieces for 78x, 56x, 39x

2.4" ALTAZIMUTH ($31 Down) **$125**
with eyepieces for 100x, 72x, 50x, 35x

2.4" EQUATORIAL ($56 Down) **$225**
with eyepieces for 129x, 100x, 72x, 50x, 35x

3" ALTAZIMUTH ($66 Down) **$265**
with eyepieces for 171x, 131x, 96x, 67x, 48x

3" EQUATORIAL ($108 Down) **$435**
with eyepieces for 200x, 131x, 96x, 67x, 48x

3" PHOTO-EQUATORIAL ($137 Down) **$550**
with eyepieces for 200x, 171x, 131x, 96x, 67x, 48x

4" ALTAZIMUTH ($116 Down) **$465**
with eyepieces for 255x, 219x, 170x, 122x, 84x, 61x

4" EQUATORIAL ($196 Down) **$785**
eyepieces for 255x, 219x, 170x, 122x, 84x, 61x, 38x

4" PHOTO-EQUATORIAL ($222 Down) **$890**
eyepieces for 255x, 219x, 170x, 122x, 84x, 61x, 38x

4" PHOTO-EQUATORIAL with clock **$1175**
drive and astro-camera ($294 Down) with eyepieces for 255x, 219x, 170x, 122x, 84x, 61x, 38x, 25x

4" PHOTO-EQUATORIAL with clock **$1280**
drive, fixed pier, astro-camera ($320 Down) with eyepieces for 255x, 219x, 170x, 122x, 84x, 61x, 38x, 25x

All models come with air-spaced, coated objective; eyepieces; duraluminum tube; rack-and-pinion focusing; view finder with crosshair eyepiece; sunglass; star diagonal; tripod mounting with slow-motion and rapid-motion controls for two co-ordinates; cabinets; instructions; and standard accessories. Additional eyepieces and accessories available for all models. Choice of UNIHEX Rotary Eyepiece Selector or star diagonal and erecting prism system for terrestrial observation in all models except the 1.6".

Use Our EASY PAYMENT PLAN

The UNITRON Easy Payment Plan is a convenient and economical way to buy your UNITRON Refractor when you do not want to disturb your savings or when you haven't the total cost of the telescope immediately available. The down payment required is 25%. The balance due is payable over a 12-month period, and there is a 6% carrying charge on the unpaid balance. Your first payment is not due until 30 days after you receive the instrument, and if you should want to pay the entire balance due at that time, the carrying charge is canceled.

There is no "red tape" when you order — you merely fill in the UNITRON Easy Payment Order form, return it to us together with the required down payment, and the model of your choice is shipped to you at once. Whether you buy your UNITRON on the Easy Payment Plan or pay for it all at once, your purchase will bring you a lifetime of trouble-free enjoyment. Far more UNITRONS are sold than any other equivalent telescopes — there must be a reason!

HOW TO ORDER

Send check or money order in full or use our Easy Payment Plan, as described above. Shipments made express collect. Send 20% deposit for C.O.D. shipment. All instruments fully guaranteed.

Here indeed is exciting news to launch the New Year. UNITRON's New Catalog has been conservatively judged by many to be the most elegant and completest publication of its kind ever issued anywhere, by anyone, at any time, since Galileo's first celestial observations with a telescope. An especially noteworthy feature of the catalog is the "Observer's Guide," a series of full-page, illustrated articles of general astronomical interest.

For example, the novice will particularly appreciate the section on "Observing the Constellations," which contains a reproduction of a star map by H. A. Rey, author of *The Stars, A New Way to See Them* (published by Houghton Mifflin). Those observers whose telescopes provide only a few magnifications will want to refer to the article, "Observing the Moon," to see the series of photographs showing how the moon appears under varying magnification. Other subjects covered include "Observing the Sun," "Observing the Planets," "Wonders of the Deep Sky," "Amateur Clubs and Research Programs," "Hints on Observing," and "How to Choose a Telescope." We have even included a glossary on telescope terminology to help introduce the beginner to the fascinating hobby of astronomy. Whatever your state of astronomical sophistication, you will find something in the catalog to justify giving it a permanent place on your bookshelf.

And, by the way, we have included complete and up-to-date information on the famous UNITRON Refractors. All models are fully illustrated with large, clear photographs which set a new standard for excellence. You will also learn about all the new UNITRON accessories, some of which have never before been pictured or described.

In conclusion, this copious and colorful celestial cyclopedia, collated from certified-canonical compositions, constitutes a comprehensive compendium crammed with the cream of cosmic chit-chat calculated to charm the connoisseur, captivate the clever, content the curious, and confound our competitors. Even contains clever cartoons to convulse the comic! A chef-d'oeuvre of craftsmanship to cherish and covet, this celebrated catalog of the century, the climax of ceaseless creation, complete with current calendar*, all complimentary, comes by carrier when called for by a clear calligraph on your card or communique.

If you have requested our telescope literature on any previous occasion, please do not write again since your name is on our mailing list and you will automatically receive a copy. Distribution is now being made as rapidly as conditions permit.

** This year, we have again printed the Julian Day Calendar for the American Association of Variable Star Observers. A copy of the calendar will be sent to you along with the catalog.*

TELESCOPE ACCESSORIES by UNITRON

1. VIEW FINDER (As shown on UNITRON 2.4" Equatorial): 23.5-mm. (.93") achromatic objective, 6x eyepiece with crosshairs. Chromed brass tube. Mounting brackets with centering screws.

Only $8.50 postpaid

2. VIEW FINDER (As shown on UNITRON 3" Altazimuth): 30-mm. (1.2") coated achromatic objective and 8x eyepiece with crosshairs. Other details as in View Finder 3.

Only $10.75 postpaid

3. VIEW FINDER (As shown on UNITRON 4" Refractors): 42-mm. (1.6") coated achromatic air-spaced objective. 10x eyepiece with crosshairs. Duraluminum tube finished in white enamel. Dewcap. Furnished with mounting brackets with centering screws for collimation. This finder also makes an excellent hand telescope for spectacular wide-field views of the sky.

Only $18.00 postpaid

UNIHEX ROTARY EYEPIECE SELECTOR: The old-fashioned method of fumbling with eyepieces in the dark has been outmoded by UNIHEX, UNITRON's new Rotary Eyepiece Selector. With UNIHEX, you always have 6 magnifications ready at your fingertips. To change power, merely rotate a new eyepiece into position while the object stays centered and in focus in the field of view. Model A is designed to fit the UNITRON rack and pinion and is for UNITRONS only. Model B fits 1¼" eyepiece holders. Complete with special clamping device and cabinet. A or B:

Only $24.75 postpaid

SUN PROJECTING SCREEN APPARATUS: White metal screen with matching black metal shade. Chromed brass extension rod with mounting brackets.

Set for 2.4" models	**Only $9.75 postpaid**
Set with screen 6" x 6"	**Only $13.50 postpaid**
Set with screen 7" x 7"	**Only $15.75 postpaid**

PHOTOGRAPHIC GUIDE TELESCOPE (As shown on 3" Photo-Equatorial): 62-mm. (2.4") diam., 700-mm. (27.5") focal length, coated, air-spaced, achromatic objective. 78x (9-mm.) achromatized symmetrical eyepiece with crosshairs. Star diagonal. Duraluminum tube finished in white. Dewcap. Rack-and-pinion focusing. Mounting brackets and centering screws for collimation. Fitted wooden cabinet.

$75.00 f.o.b. Boston

DUETRON Double Eyepiece: With DUETRON, two observers may use the telescope simultaneously and with equal comfort. The eyepieces used need not necessarily be of the same magnification. DUETRON is a real boon for father-and-son observing teams. With DUETRON, more observers may be accommodated at star parties, and the advanced members may provide valuable instruction to the beginners. The tube of DUETRON Model A is interchangeable with the customary UNITRON drawtube and may be used with all models with the exception of the 1.6" Refractor. DUETRON Model B fits 1¼" eyepiece holders. Complete with special clamping device and cabinet. A or B:

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JANUARY METEORS

The Quadrantid shower is best observed in the morning hours of January 4th. Recent studies indicate that the duration of this shower is one day. At maximum activity and under excellent sky conditions, 35 meteors per hour would be expected. However the moon is at last quarter on the 4th, rising about midnight, so observed rates may be somewhat lower. The radiant of these medium-speed meteors is in northern Bootes, at $15^h\ 24^m$, $+50°$. E. O.

MOON PHASES AND DISTANCE

Last quarter	January	4, 22:41
New moon	January	13, 03:01
First quarter	January	20, 22:58
Full moon	January	27, 14:40
Last quarter	February	3, 16:08

	January	Distance	Diameter
Apogee	11, 08^h	252,500 mi.	29′ 24″
Perigee	26, 13^h	222,900 mi.	33′ 19″
	February		
Apogee	7, 19^h	252,100 mi.	29′ 27″

VARIABLE STAR MAXIMA

January 9, Omicron Ceti, 021403, 3.7; 14, R Cassiopeiae, 235350, 6.5; 21, T Aquarii, 204405, 7.9; 23, R Carinae, 092962, 4.6; 27, Z Ursae Majoris, 115158, 6.6; 29, RS Herculis, 171723, 8.0. February 1, T Hydrae, 085008, 7.7; 2, R Indi, 222867, 8.0; 3, R Virginis, 123307, 6.9; 6, S Canis Minoris, 072708, 7.5; 8, R Centauri, 140959, 5.9.

These predictions of variable star maxima are by the AAVSO. Only stars are included whose mean maximum magnitudes are brighter than magnitude 8.0. Some, but not all of them, are nearly as bright as maximum two or three weeks before and after the dates for maximum. The data given include, in order, the day of the month near which the maximum should occur, the star name, the star designation number, which gives the rough right ascension (first four figures) and declination (bold face if southern), and the predicted magnitude.

MINIMA OF ALGOL

January 1, 11:18; 4, 8:07; 7, 4:57; 10, 1:46; 12, 22:35; 15, 19:24; 18, 16:14; 21, 13:03; 24, 9:52; 27, 6:41; 30, 3:30. February 2, 0:20; 4, 21:09; 7, 17:58; 10, 14:48.

These minima predictions for Algol are based on the formula in the 1953 *International Supplement* of the Krakow Observatory. The times given are geocentric; they can be compared directly with observed times of least brightness.

SUNSPOT NUMBERS

October 1, 32, 37; **2**, 54, 54; **3**, 69, 58; **4**, 68, 64; **5**, 61, 62; **6**, 53, 60; **7**, 82, 71; **8**, 64, 71; **9**, 69, 79; **10**, 61, 56; **11**, 64, 55; **12**, 43, 61; **13**, 36, 41; **14**, 10, 22; **15**, 6, 7; **16-18**, 0, 0; **19**, 15, 11; **20**, 26, 21; **21**, 30, 31; **22**, 47, 42; **23**, 57, 57; **24**, 81, 86; **25**, 95, 95; **26**, 102, 107; **27**, 92, 98; **28**, 97, 108; **29**, 120, 119; **30**, 109, 124; **31**, 107, 123. Means for October: 56.5 American; 58.7 Zurich.

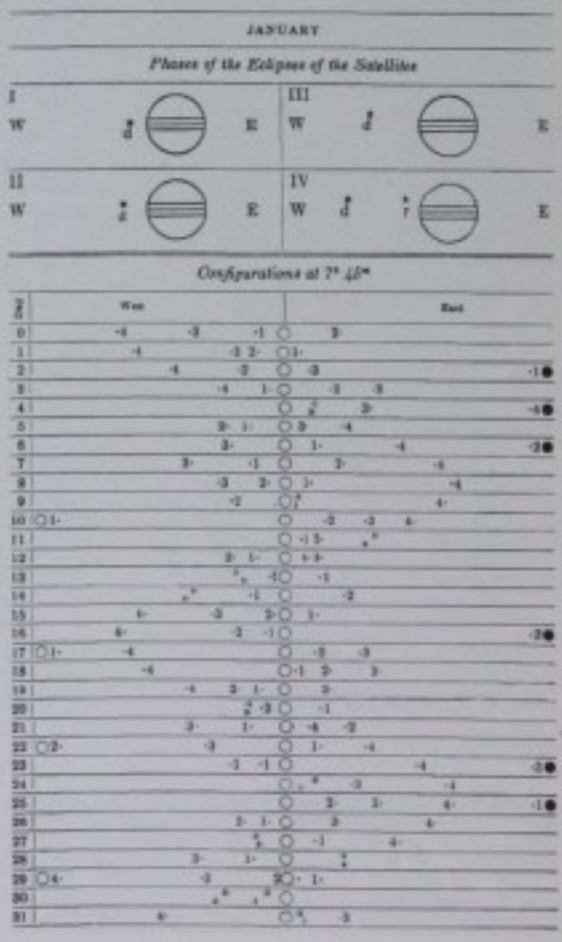
Above are given the date, the American number, then the Zurich number. These are observed mean relative sunspot numbers, the American computed by D. W. Rosebrugh from AAVSO Solar Division observations, the Zurich numbers from Zurich Observatory and its stations in Locarno and Arosa.

Smoothed monthly sunspot numbers for coming months are predicted as follows by Zurich Observatory: January, 63; February, 69; March, 74; April, 80.

JUPITER'S SATELLITES

The configurations of Jupiter's four bright moons are shown below, as seen in an astronomical or inverting telescope, with north at the bottom and east at the right. In the upper part, *d* is the point of disappearance of the satellite in Jupiter's shadow; *r* is the point of reappearance.

In the lower section, the moons have the positions shown for the Universal time given. The motion of each satellite is from the dot toward the number designating it. Transits over Jupiter's disk are shown by open circles at the left, eclipses and occultations by black disks at the right. The chart is from the *American Ephemeris and Nautical Almanac*.



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FIBERGLASS telescope tubes, orthoscopic oculars, parabolic mirrors, spiders, elliptical diagonals. What you want we sell. Harold Snyder, Walbridge, Ohio.

UNITRON 4" equatorial with regular accessories, plus Brandon objective, four 1¼" eyepieces, Ross diagonal, Barlow lens. In wooden cases. $500.00. Thornton Howell, 762 St. John Ave., Pasadena 2, Calif.

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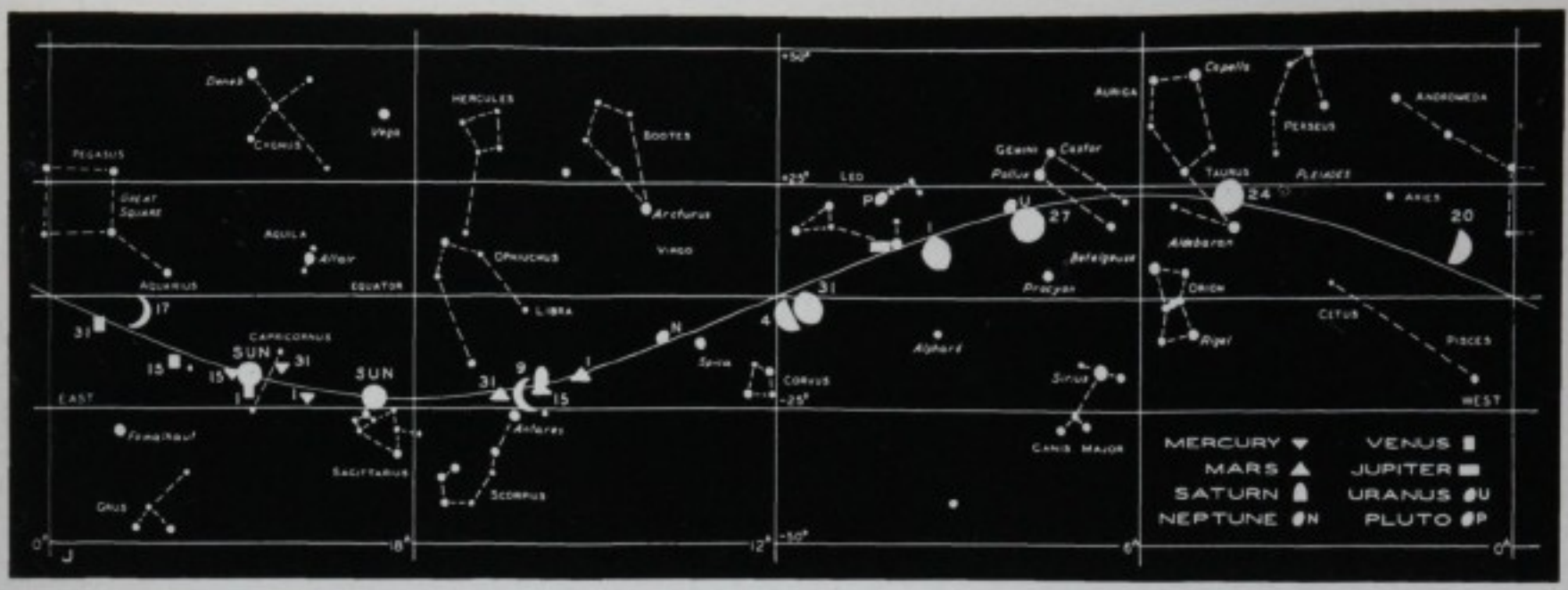
WANTED to buy: A complete sequence of *Sky and Telescope* including 1950 to present. David Dickinson, R. D. 1, Box 102A, State College, Pa.

COMBINATION 12" f/5 Newtonian-Cassegrain, Porter design, see page 449 ATM. Electrically controlled, all accessories. Also 12" Springfield mount, Scanlon design, complete with sidereal drive, finished cell and diagonal holder. Optics and tube not furnished. Also 6" f/8 Springfield Pierce design complete. Also Longines 25-jewel 2-dial sidereal watch. Photos on request. Questar wanted, will pay cash. B. Wacek, 101 Wendover Rd., Baltimore 18, Md.

REFLEX CAMERA, Astra 35-mm. f/1.9 lens; extension tubes for attaching telescope; brand new $75.00 Busch Pressman 2¼ x 3¼ camera, with rangefinder, focuspot, f/4.5 Raptar lens, Heiland flash; like new $95.00. Goodwin Barlow $10.00. Mogey ½-inch eyepiece $5.00. Hopf Photography, 31 Kalbfus, Newport, R. I.



THE SUN, MOON, AND PLANETS THIS MONTH

The sun, on the ecliptic, is shown for the beginning and end of the month. The moon's symbols give its phase roughly, with the date marked alongside. Each planet is located for the middle of the month and for other dates shown.

Mercury may be viewed in the evening sky during the first half of January. Greatest elongation is attained on the 11th, 19° 01′ east of the sun. The elusive planet then appears at magnitude −0.4, setting 1½ hours after the sun. After this, Mercury fades rapidly, as it moves swiftly to inferior conjunction with the sun on January 27th.

Venus, now a prominent object at magnitude −3.4, may be seen in a dark sky, for it sets 2½ hours after the sun in midmonth. Then its disk will be 13″ in diameter and 83 per cent illuminated. Venus travels through Capricornus and Aquarius during the month.

Mars begins the year as an inconspicuous 2nd-magnitude object traveling eastward in Libra and Scorpius. Together with Saturn it rises four hours before the sun in the middle of the month, and Mars passes 1° 33′ south of Saturn at the conjunction on January 14th. During the week of the 22nd, while Mars travels a path only 5° north of Antares, a comparison of these two red objects should be interesting.

Jupiter rises as evening twilight ends in late January, appearing at magnitude −2.0. In retrograde motion, the giant planet goes by Regulus for the second time in a series of three conjunctions. On the evening of the 27th, Jupiter will be 42′ north of Regulus. The Jovian disk is to be 43″ in diameter on the 15th, recognizable in good binoculars.

Saturn will be close to Mars in the morning sky; their conjunction has been described above. Moving slowly eastward among the stars, Saturn now is of magnitude +0.8. The ring system is inclined 24°.5 to our view on January 15th, with its northern side visible.

Uranus comes to opposition with the sun on the 21st, appearing like a 6th-magnitude star. This distant planet is moving westward in Cancer, about 1½° southeast of Mu Cancri. Visible in binoculars, Uranus will be at right ascension 8ʰ 11ᵐ.6, declination +20° 37′ (1956) on January 15th.

Neptune, at western quadrature with the sun on January 21st, can be seen only during morning hours. This 8th-magnitude planet is about 8° east of Spica in Virgo, and on the 15th is at 13ʰ 55ᵐ.4, −9° 59′ (1956). E. O.

UNIVERSAL TIME (UT)

TIMES used on the Observer's Page are Greenwich civil or Universal time, unless otherwise noted. This is 24-hour time, from midnight to midnight; times greater than 12:00 are p.m. Subtract the following hours to convert to standard times in the United States: EST, 5; CST, 6; MST, 7; PST, 8. If necessary, add 24 hours to the UT before subtracting, in which case the result is your standard time on the day preceding the Greenwich date shown.

PREDICTIONS OF BRIGHT MINOR PLANET POSITIONS

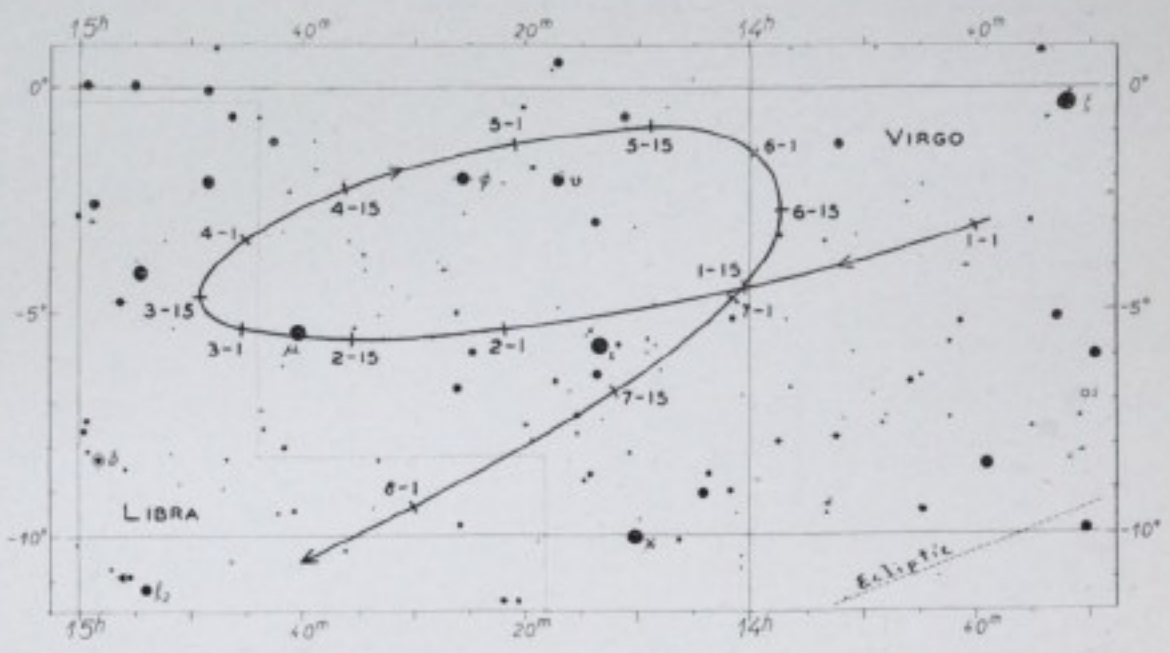
Diana, 78, 9.3. Dec. 19, 8:02.3 +32-44; 29, 7:54.9 +32-56. Jan. 8, 7:44.6 +32-54; 18, 7:33.2 +32-35; 28, 7:22.6 +31-55. Feb. 7, 7:14.6 +30-59.

Flora, 8, 8.5. Dec. 19, 8:06.6 +19-04; 29, 7:58.7 +20-04. Jan. 8, 7:48.3 +21-13; 18, 7:36.7 +22-20; 28, 7:26.1 +23-20. Feb. 7, 7:17.8 +24-08.

Nemausa, 51, 9.6. Jan. 8, 9:17.0 +2-46; 18, 9:10.7 +3-18; 28, 9:02.4 +4-13. Feb. 7, 8:53.2 +5-30; 17, 8:44.4 +7-00; 27, 8:37.4 +8-33.

Iris, 7, 8.8. Feb. 7, 11:04.7 −3-09; 17, 10:56.3 −2-40; 27, 10:46.7 −1-52. Mar. 8, 10:36.9 −0-53; 18, 10:28.2 +0-10; 28, 10:21.5 +1-09.

After the asteroid's name are its number and the magnitude expected at opposition. At 10-day intervals are given its right ascension and declination (1950.0) for 0ʰ Universal time. In each case the motion of the asteroid is retrograde. Data are supplied by the IAU Minor Planet Center at the University of Cincinnati Observatory.



The path of the brightest asteroid, Vesta, from January 1, 1956, to August 1st, is plotted here. During this period, Vesta completes its retrograde loop in Virgo and Libra. In January, the asteroid is magnitude 7.4, brightening to 6.0 at opposition to the sun on April 28th, then fading to 7.0 by July. The chart is modified from the Skalnate Pleso Atlas of the Heavens, which shows stars to magnitude 7.75, and thus Vesta will be brighter than the faintest stars shown. The asteroid can be seen with binoculars during this period, and in April and May with the unaided eye if conditions are excellent.

STARS FOR JANUARY

The sky as seen from latitudes 30° to 50° north, at 9 p.m. and 8 p.m., local time, on the 7th and 23rd of January, respectively; also at 7 p.m. and 6 p.m. on February 5th and 21st. For other dates, add or subtract ½ hour per week.

For northern observers, this is the most striking sky of the year, with Orion and his followers dominant in the middle part of the heavens. The Great Square stands on one corner in the west, while Leo makes his appearance in the east, a harbinger of spring.

Brandon Orthoscopic Oculars

☆ During the past ten years, we have produced several thousand of our orthoscopic oculars, which have been highly praised by the casual amateur observer as well as the serious professional astronomer throughout the world.

☆ Many attempts have been made to duplicate both the appearance and performance of these oculars. The market has been flooded with war-surplus optics and Oriental and European imports for which the performance is often mediocre. These less satisfactory eyepieces have actually increased our sales.

☆ To keep pace with the demand, we have established our research and production facility in Puerto Rico. Here we have willing American labor, ideal climatic conditions to produce quality optical components, and unlimited visibility both day and night for field testing. We are confident we can produce the finest astronomical components available at competitive prices.

☆ Rather than resort to high-pressure claims, we prefer to let our oculars sell themselves. We only ask that before you purchase your next eyepiece you consider its performance. This may be confirmed for Brandon oculars by consulting your local planetarium or observatory, your astronomical society, or your college or university science department. Of course our best salesman is the owner of a Brandon ocular.

☆ We urge you to purchase an eyepiece 1¼ inches in diameter, regardless of who makes it—most imported eyepieces have substandard diameters, with necessarily smaller lens components that seriously restrict the field of view.

☆ The painstaking care that you have put into your mirror or telescope can be nullified by an inferior eyepiece. We sincerely believe the Brandon orthoscopic ocular is the best available, regardless of price. Here's why:

1. Four-element design giving a flat, beautifully corrected field of 50° covering more than 160 per cent of the area of the conventional Ramsden for the same power. This eyepiece is a "must" for RFT work.
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These eyepieces are produced in 4-mm., 8-mm., 16-mm., and 32-mm. effective focal lengths.

$15.95 each, postpaid

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We can also ship from stock quality astronomical objectives with the following features:

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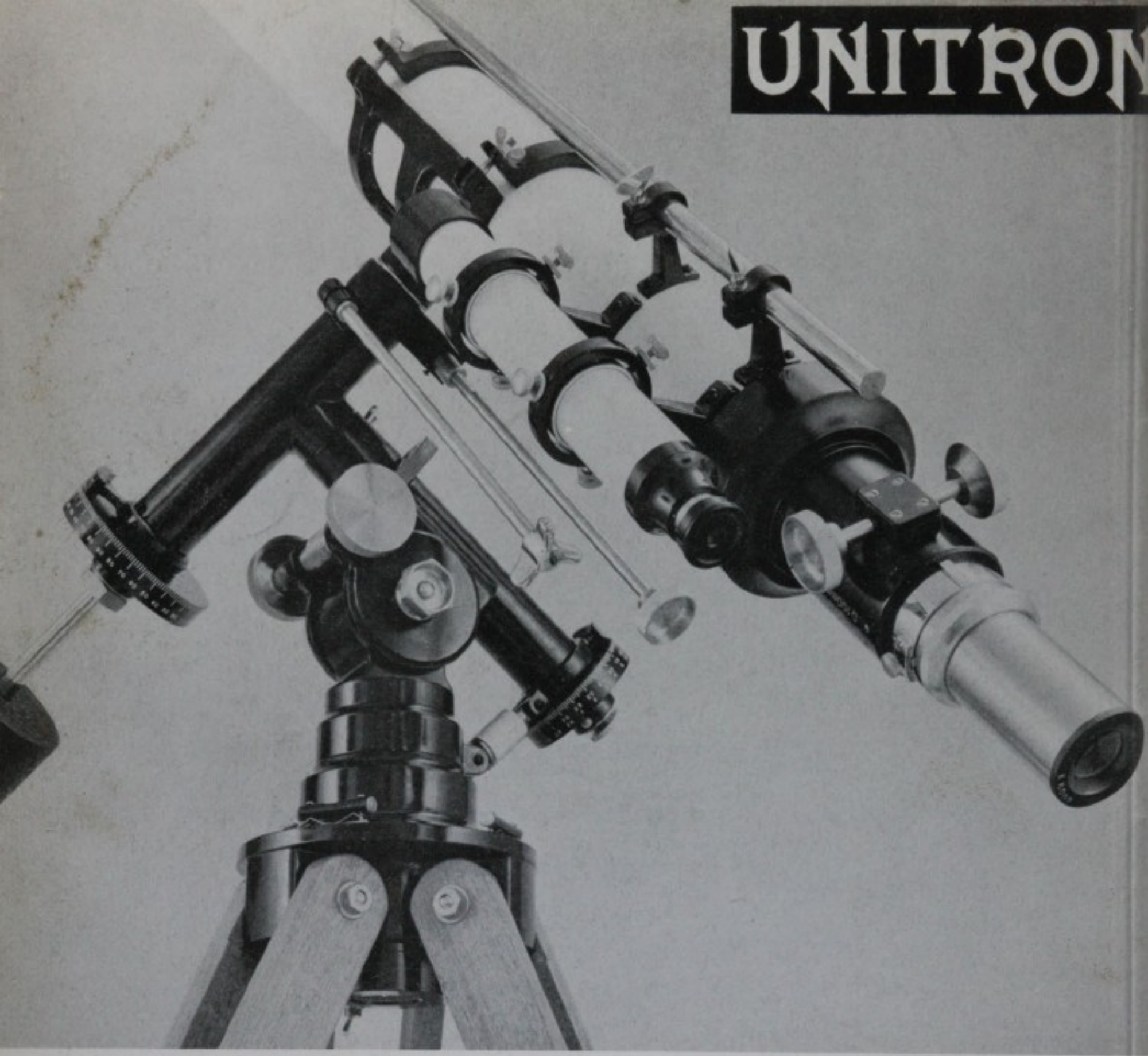

UNITRON 4-inch Refractors for 1956 offer new features and more accessories . . . *all at no additional cost!*

Despite steadily rising manufacturing costs, UNITRON's 4" Refractors for 1956 actually give you more equipment than ever before . . . and all **at no additional cost.**

For example, take UNITRON Model 152, the 4" Equatorial Refractor pictured above. With this popular model, we now include as standard equipment the new Super Rack-and-Pinion focusing device, the same as supplied with the clock-drive Models 160 and 166. This massive mechanism uses a drawtube, 2.4 inches in diameter, to provide for the accessory 60-mm. f.l. wide-field eyepiece and the giant accessory Super-UNIHEX. This new mammoth rotary eyepiece selector can accommodate the giant 60-mm. eyepiece, the 40-mm. eyepiece, and four additional oculars. (While it has not yet been formally unveiled in these pages, you may obtain a peek at the Super-UNIHEX attached to the 4" on page 142.) In addition to the new Super Rack and Pinion, buyers of UNITRON Model 152 ($785.00) will also receive as standard equipment the wide-field 40-mm. eyepiece which gives a magnification of 38x with the 4" models.

This brings to seven the number of eyepieces included with this model in the purchase price. The extra eyepiece plus the new rack and pinion represents extra value of $46.75, all **included at no additional cost.**

With the UNITRON 4" Photographic Equatorial Model 155 ($890.00), not only are the new Super Rack and Pinion and 40-mm. eyepiece included, but we are also adding the UNIBALANCE Tube Assembly with adjustable counterweight. These extra features are valued at $69.50, all **included at no additional cost.**

We also have a bonus for buyers of Model 150, the UNITRON 4" Altazimuth Refractor ($465.00). The mounting of this model now includes a newly designed azimuth slow motion using a worm gear mechanism to provide continuous adjustment. This valuable extra feature is now **included at no additional cost.**

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Accessory eyepieces of 4-mm. and 5-mm. f.l. will be offered for sale very shortly. This will bring to 10 the number of magnifications obtainable with these 4" models.

See pages 142 and 143.

United Scientific Co.

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